THE READINESS ASSESSMENT OF THE SOCIAL DIMENSION OF SOCIO -TECHNICAL SYSTEM ON A LEVEL SCALE

Based on

Cases of Renewable Energy Development at Tata Steel IJmuiden

By

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in partial fulfilment of the requirements for the degree of

Master of Science

In Complex Systems Engineering and Management

at the Delft University of Technology to be defended publicly on Monday Septmber 17, 2018 at 10.00

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This thesis is confidential and cannot be made public until –

Abbreviations

CA	Collaboration Agreement
CCA	Central Coordinating Actor
CCS	Carbon Capture and Storage
DGO	Duurzame Gebieds Ontwikkeling
DH	District Heating
DOI	Declaration of Intent
DSO	District System Operator
ECN	Energie Onderzoekcentrum Nederland
ESA	European Space Agency
HSM	Hot Strip Mill
IRR	Internal Return Rate
LoD	Level of Development
LOI	Letter of Intent
MKBA	Maatschappelijke Kosten Baten Analyse
MRA	Metropool Regio Amsterdam
NASA	National Aeronautics and Space Administration
NDA	Non-Disclosure Agreement
NPV	Net Present Value
OD NZKG	Omgevingsdienst Noordzeekanaal Gebied
OD IJmond	Omgevingsdienst IJmond
RFI	Request for Information
RIS	Regional Innovation System
ROI	Return on Investment
SROPTTC	Site, Resource, Off-take, Permits, Technology, Team, and Capital
STS	Socio –Technical System
TF	Theoretical Framework
TIS	Technology Innovation System
TSIJ	Tata Steel IJmuiden
U.S. DoD	United States Department of Defense

Abstract

In a socio –technical system, such as the energy system, a network of actors is responsible for developing, monitoring and managing the technical system bounded by institutions on different levels. The network of actors is the social dimension, where the technical system is the technical dimension of the socio -technical system. The development of the technical dimension can already be assessed through the Technology Readiness Level (TRL). The development of the network of actors, or the social dimension; the dimension that mostly causes problems cannot be assessed at this time.

It is, therefore, the aim of this thesis to create a numerical scale that indicates the development of the social dimension of a socio -technical system; the Network Readiness Level (NRL). The scale indicates the development at a low level of analysis; individual projects adding to the bigger socio -technical system. To draft the NRL -scale, the following research question should be answered: 'What should a numerical indicator to assess the readiness of the social dimension of a socio -technical system look like?

To answer the research question, a list of properties, facilitators and barriers of influence on a socio –technical system was drafted, based on literature. The list was validated by experts based on semi –structure interviews and a sorting exercise. The experts were originating from cases on renewable energy development of Tata Steel IJmuiden . A total of three cases on the development of a wind park, developing solar power at TSIJ, and developing a District Heating network were used. All cases were selected based on their socio -technical characteristics. The outcomes of the interviews served as an input for a 4-step result analysis that lead to the final outcome of this thesis: the NRL –indicator.

The NRL -indicator is a methodology to assess the readiness of a network of actors based on a numerical scale. It serves to indicate the level of development, and addresses what causes the development to lag behind. The NRL -indicator exists of 16 criteria of a collaboration, and a scale of seven levels (NRL1 -NRL7). The methodology includes three important characteristics of a development: dynamic character, different criteria present at the same time, and the development process of the criteria. By combining these criteria, the NRL -indicator is capable of providing a complete overview of the factors of influence on a socio –technological development. The NRL –indicator presents something, a numerical scale to assess the readiness of the social side, which has never been presented before.

This research on the NRL –indicator thus proposes a completely new methodology that could be valuable for managers, policy makers, and other actors in the network of actors of any socio -technical system. Future research is needed to validate the methodology, and prove its applicability. Not only in renewable energy development, but in multiple socio -technical systems, like: construction, pharma, transportation, communication, public -private partnerships, and innovation.

Acknowledgements

During my graduation internship at Tata Steel IJmuiden I have gained a lot of experience in writing the thesis, and working outside of the universities' environment. My time at Tata Steel IJmuiden was a perfect connection to my time abroad, because of the new insights and all the new people that I have met.

I would like to express my thanks to Gerard Jägers, my supervisor at the department of Energy Efficiency, for the opportunity he has given me, the time has spent on supervising my research, and the new insight he has brought me. Especially our conversations, and the laughter we have had besides the research will stay with me. Also I would like to thank my colleagues at Energy Efficiency, and my fellow interns for supporting me, and helping during my time at Tata Steel. A special thanks goes out to Rob Stikkelman, my supervisor at TU Delft, for supporting me and structuring my many thoughts on this difficult topic. During our meetings every other week he supplied insights into how to approach the topic, and how to concretize my thoughts, which has led to this thesis. Our meetings were not only about the topic, but we have discussed many things, and I have enjoyed working together with him. Furthermore, I would like to thank my thesis committee in the person of Margot Weijnen and Daniël Scholten for their help, and critical view on this thesis.

Finally, I would like to thank all the interviewees of this thesis, because without them it would not have been possible to conduct the research. I have enjoyed conducting the interviews, due to the diverse set of respondents, the diverse environments in which the interviews took place, and the many interesting insights. The overall responses to the research were positive, and respondents reacted surprised, but also approvingly to the open questions and the sorting exercises. I would like to thank them for their time and responses.

Overall, the writing of the thesis was a stressful, but also a satisfying task. I have been able to express my knowledge, and thoughts on collaborations in networks of actors. Hopefully I have drafted a contribution to theory, and a valuable methodology for future use.

Julius Groenendaal

Tata Steel IJmuiden , July 2018

Contents

Chapter 1

Introduction

1.1 Introducing the background of this thesis

In 2013 the Dutch government presented its goals for reducing GHG (Greenhouse Gas) emissions, and increasing the amount of renewable energy in the energy mix to 14% in 2020, and 16% in 2023. These goals were presented in the Dutch Energie Akkoord. The Energie Akkoord is an agreement between representatives of different sectors, and backgrounds. The agreement presents the goals, focal points, and policy to aim for a climate-neutral energy supply in 2050 (Sociaal-Economische Raad, 2013). Since the Energie Akkoord already dates back to 2013, new negotiations between sector representatives are taking place. This lead to a preliminary draft of a new Energie Akkoord, but no signed agreement is present at the moment (Klimaatberaad, 2018). The authors of the new energy agreement aim at introducing renewable energy, new energy generation methods, and new coalitions of actors into the existing energy system, thereby changing the existing energy system. Changing the energy system is challenging due to its socio -technical characteristics.

The energy system is a complex socio -technical system in which a network of actors develops, maintains, and manages the technical system, bounded by institutions on different levels. These are the three pillars of a socio -technical system (Moncada, 2017;Verbong, 2010). The network actors are the individuals, companies, organizations etc. that make decisions, collaborate with each other, and play different roles in the system. The institutions are the guidelines, constraints and rules for the actors that shape the interaction between the actors and between the actors and the technical system. The technical system contains all the technical artefacts in the system; infrastructure, technologies, resources etc. A change in an existing socio -technical system means a change in the institutions, and the technical systems' design, influencing the network of actors on multiple levels (Moncada, 2017).

In the current Dutch energy system a large coalition of companies and actors responsible for generation, distribution, and sales of electricity exists. A dense and reliable infrastructure is present, with clearly defined roles for all actors, and a regulated electricity market (Donker, 2015). The system is based on burning fossil fuels; gas, coal, oil to generate electricity in large centralized power plants (Ministry of Economic Affairs, 2016). This burning of fossil fuels, however, emits greenhouse gasses. The emission of the greenhouse gasses is why a transition away from the use of fossil fuels is currently taking place; the so-called 'energy transition'(Sociaal – Economische Raad, 2013; Bosman et al. ,2014). The transition away from the use of fossil fuels to the use of renewable energy sources (solar, wind) in the energy system, causes the networks of actors, the institutions, but also the technical system to change at multiple levels in society.

At the highest level, or macro level, the Dutch energy system is influenced by the energy policy of surrounding countries. This is caused by the interconnectedness of the electricity grid, and the electricity market. Increased generation of renewable energy in surrounding countries has an impact on the Dutch energy system. On the other hand, at the low level, or micro level of the energy system, regional collaboration and smaller renewable energy projects in the Netherlands have an increasing impact on the energy system (ECN, 2017). The growing importance of this low level is further demonstrated by: regional energy initiatives, energy cooperation's in urban areas, the growing role of cities and municipalities in the transition, and the rise of regional energy strategies. The energy system thus existed of a large coalition of actors and companies. The energy transition causes a change in the system; at the higher level by interconnectedness with other countries, causing new actors to enter the system, but also on a lower level by new networks of actors that wish to change the energy system by conducting renewable energy projects. This leads to the idea that all the changes in the complex energy system, no matter how small, have a technical, physical, and social dimension, that has to connect to the bigger energy system. Even the smallest renewable energy project could be a socio -technical system that contributes to the larger complex socio -technical energy system. The small scale project causes new actors to become present in the network of actors, new institutions to be necessary, and new (small scale) technologies to be implemented in the technical system. It is these small scale socio -technical systems that are the subject of this thesis.

An example of these small scale socio -technical systems are the cases of renewable energy and residual heat development at the site of Tata Steel IJmuiden . The company is engaged in different networks of actors to conduct a solar panel, a wind park, and district heating project. In these projects, networks of different public and private actors are working together to develop an addition to the existing technical system. As an example; the development of the wind park is executed together with the provincial, and local government, and multiple external firms. The potential of the wind turbines, and the connection to the electricity grid makes the project add to the technical system. Provincial decrees on the development of wind parks limit the possibilities of the wind park, making the institutions play an important role. The development of the wind park at the TSIJ -site is thus an example of a small scale socio -technical system adding to the larger socio -technical system.

In these socio -technical systems it is not necessarily the technical dimension, that influences the development, but more the accountability in the project, the division of power and the arrangements about risk. In other words the social dimension of the socio -technical system (Flyvbjerg, 2003; Corsaru, Cantù, & Tunisini, 2012; Lippert & Nykerki, 2011). Trying to combine different interests, resources, and perspectives in a network, becomes a difficult task (Newell, 2017; Negro, 2012; Lutz, 2017). It is the social factors in a collaboration that are mostly invisible, but influence a collaboration negatively once they emerge (van Kempen, 2010). The social dimension of the socio -technical system in this thesis, is seen as a network of actors interacting with each other to develop, maintain and manage the technical system. This description is based on the three pillar representation that was proposed by (Moncada, 2017).

Since the network of actors influences the development of the technical dimension; a method to monitor, indicate, and assess the development of a network of actors could be valuable. To indicate and communicate the development of the technical dimension a methodology already exists. The TRL -scale (Technology Readiness Level) was introduced by NASA in the 1980's. The TRL -scale served as a way to unify communication about the development of a technology, and was later adapted and applied in multiple different technological sectors (Mankins, 1995; Mankins, 2009). The scale exists of nine levels of development, in which each level is determined by a condition that has to be met by the technology. If the condition is met, the technology is assigned the level of development.

Inspired by the social dimension of an innovation network, and the existing TRL -scale, a proposal for a NRL -scale (Network Readiness Level) to indicate the readiness of the network of actors, was proposed in a thesis by D. Krijger. The NRL -scale was created to indicate the process of development of a network of actors working together to introduce innovation in the network. In the thesis a case of introducing an innovative technology (Demand Response) in a network of actors was used to draft a first version of the NRL -scale.

1.2 Research Problem

The NRL -scale of Krijger is only a first version of a methodology and needs improvement, which was also mentioned by Krijger is his thesis. The author was interested in proposing the idea of the NRL instead of drafting an applicable methodology. The existing NRL -scale is not applicable to real life cases, due to multiple reasons. At first, the NRL -scale is based on a framework for Innovation Networks, and developed by studying a case of introducing an innovation in a network. Socio-technical systems have a much broader scope than innovation in a network, due to the presence of both public and private actors, institutions influencing the system, and the pursued change of the technical system. This makes the NRL of Krijger limited in its applicability to networks of actors in socio -technical systems, causing the need to develop an improved version. Besides this, the NRL -scale is based on studying just one network, which ask for practical validation, or a methodology drafted based on more cases. As a third reason, the NRL -scale proposes many factors of influence on a network, but does not connect these factors to theory. There is no strong theoretical backing for the included factors in the NRL -scale. Furthermore, the methodology is capable of indicating what influences a network at a specific moment, but is not capable of determining the real level of development of the studied network. The methodology is not capable of following the development of a network, due to its rigid structure. Finally, the NRL -scale could be expanded by including more factors of influence, and more indicators for the levels of development to make the scale applicable to real life networks of actors.

Based on the above reasons, the existing scale is not applicable to real life cases of low level networks of actors aiming to add to the technical system, such as the cases of Tata Steel Ijmuiden. Tata Steel has indicated they want to find out what factors are of influence on a network of actors, and how they could structure future socio -technical projects better. The aim of this thesis is, therefore, to draft an improved version of the NRL -scale, by using the cases of Tata Steel. These cases have socio -technical characteristics and form the input of the new draft. The improved version of the NRL -scale could be used in future cases by the company, and many other users in a socio -technical project. The new NRL -scale should be an improvement since it will be based on three cases of a socio -technical system on a low level, the factors that are included will be validated based on expert opinions and theory. Besides, the methodology will be able to indicate a level of development, and the development of the network can be followed. Finally, the new methodology will include more factors of influence, making it a more extensive version of the NRL.

The final goal is to draft a numerical scale that is capable of indicating the readiness of a network of actors in a socio -technical system. The scale is drafted based on the properties, facilitators, and barriers that influence a network of actors. The scope of the research is from the moment an incentive to engage in a network of actors is present till the moment the contracts are signed. The NRL is thereby focused on the first steps to create the network of actors to develop an addition to the technical system. The physical construction is not included in the NRL -scale. The NRL of Krijger is studied for the theoretical framework used, and the research methodology. The cases of Tata Steel IJmuiden are used to provide the data on the factors of influence on a network of actors, based on expert interviews, and a sorting exercise.

1.3 Research Question

In order to solve the research problem, and create a scale to assess the readiness of a network of actors, the following research question was drafted:

'What should a scale to assess the readiness of a network of actors in a socio -technical system look like?

1.4 Sub – questions

To answer the main research question, multiple sub -questions were drafted. The answer to these sub -questions should help in answering the main research question:

1. What theoretical framework could be drafted to structure this research?
2. What factors of influence on a socio –technical system exist in literature?
3. How to validate the theoretical factors in a practical setting?
4. How to change the validated factors into a scale to assess the readiness of a network?
5. How does the scale compare to an already existing indicator for socio –technical systems ?

The first sub- questions should give an insight into the theoretical framework that was used by Krijger, and provide a new theoretical framework. The second sub- question should provide an insight into the factors of influence on a socio –technical system that are present in theory. A method to validate the theoretical factors in a practical setting should be the answer to sub –question 3. The validation leads to a set of factors that could form the input of the NRL -scale. Sub –question four is aimed at how these factors could function as an input to create a scale to assess the readiness of the social side of the socio –technical system. Finally, in sub –question five the newly created numerical indicator is compared to the already existing indicator for socio –technical system to see how the new methodology contributes to theory, and could be used in practical cases.

1.5 Societal Relevance, and the interest of Tata Steel IJmuiden

The societal relevance of the thesis lies in creating a methodology that is able to assess the readiness of a network of actors in a socio -technical system. This methodology could be used to concretize the 'soft' factors of collaboration, and provide an insight into what social factors influence a socio -technical project. The research is conducted at the Energy Efficiency department of Tata Steel IJmuiden. The relevance for Tata Steel IJmuiden is similar, since the company wishes to find out what factors influence its projects on renewable energy development. Besides this, the company wants to find out how to approach these socio -technical projects in the future. Tata Steel is engaged in different projects in which networks of actors collaborate on renewable energy, and district heating development. Some of these projects are running smoothly, while others are hindered by different barriers. The value of this thesis for Tata Steel lies in the analysis of the projects to find out what influenced the projects so far, and what could influence the further development of the projects. The developed methodology could be used to finish the current projects, and function as a tool to be used in future networks of actors.

1.6 Outline

In this thesis, the following structure of chapters is used. In Chapter 2, the research approach is presented, by introducing the different sub –questions in combination with the used research methodologies. In Chapter 3, the results of a literature study into the existing NRL -scale of Krijger are presented. The outcomes lead to two more elaborate literature studies, which are also presented in Chapter 4. One into the draft of a new theoretical framework, the other into a list of theoretical factors of influence on a network of actors. The list of factors has to be validated in this research. The experts that could be used to validate the list are presented in Chapter 5. The experts are originating from three cases of Tata Steel IJmuiden . The results of the validation, and the further analysis of the results are presented in Chapter 6. The results are presented as a four step analysis, leading to the draft of the NRL -indicator. In Chapter 7 the discussion of the research is presented. The discussion is split into a discussion on the execution of the research, and a discussion on the created NRL -indicator. The Conclusion, and recommendations are finally presented in Chapter 8. The conclusion is supplemented with research recommendations on the research in general, and on the NRL –indicator specifically. In Appendix E, a part of the result analysis is presented. The results in Appendix E functioned as an insight in the development of the new methodology, but were not included in the main part of the thesis

Chapter 2

Research Approach

In order to answer the sub -questions, and finally the main research question, different research methodologies were used in this thesis. The methodologies are presented in this chapter. The chapter is structured by using the different sub -questions as section headings. Figure 2.1 gives a summary of the different sub –questions, and the methodologies that were used to answer the sub –questions. Finally, a Research Flow Diagram (RFD) is presented as a summary of this chapter, and a graphical overview of the research approach.

Research Questions	What is the Research Question?	Research Methodology	Chapter of Presentation
Main Research Question	'What should a scale to assess the readiness of a network of actors in a socio -technical system look like?	Combination of the below mentioned methodologies.	Chapter 5
Sub – question 1	What the theoretical framework could be drafted to structure this research?	Desk Research Literature Study	Chapter 3 & 4
Sub – question 2	What factors of influence on a socio -technical system exist in literature?	Desk Research Literature Study	Chapter 4
Sub – question 3	How to validate the theoretical factors in a practical setting?	Desk Research Semi –structured interviews Sorting Exercise (based on Q-sort)	Chapter 5
Sub - question 4	How to change the validated factors into a scale to assess the readiness of a network?	4 step analysis (drafted in this research)	Chapter 6
Sub – question 5	How does the scale compare to an already existing indicator for the readiness of the network of actors?	Comparison of the two indicators based on -Background -Potential	Discussion of the Research

Figure 2.1 – Table representing the different sub –questions as the structure of this chapter. The research methodology used per sub –question is explained, and the chapter in which the sub –question is answered is presented.

2.1 Research Methodology

Sub –question 1

In order to answer the first sub –question, at first, a ***desk research*** into the existing NRL of Krijger was conducted. The aim was to look for the theoretical framework used in his study. Subsequently, a ***literature study*** to create a new theoretical framework was conducted. The literature study was conducted based on the following keywords*: 'theoretical framework for socio -technical system', 'socio technical systems/transition', 'network development/management', 'renewable energy project management', 'renewable energy development', 'theoretical framework network management'.* The results of the literature study were analysed to determine the existing theoretical frameworks, and to create a new theoretical framework based on the existing literature. The result of desk research into the NRL of Krijger is presented in Chapter 3. The results of the subsequent literature study are presented in Chapter 4.1.

Sub -question 2

A second ***desk research*** into the works of Krijger was used to determine the theoretical factors of influence on a multi -actor network. Krijger used these factors of influence on a network of actors to create his version of the NRL. The factors were referred to as; properties, facilitators, and barriers, (also PFB's). The findings of the desk research were combined with the results of a subsequent ***literature study*** to supplement the factors of Krijger with factors from literature. The following keywords were used in the literature study: *'influencing factors socio –technical development', 'barriers socio –technical development/transition','facilitators socio –technical development/transition','properties socio –technical development/transition', 'barriers/facilitators of collaboration (in projects), 'collaboration in networks of actors', 'soft –factors in collaboration'.* Once a publication was found that presented factors of influence, snowballing was used to gather more publications on the factor of influence. The results of desk research into the factors of influence of Krijger, and the literature study are presented as a list of theoretical factors of influence on a network of actors. The list is presented in three tables in Chapter 4.2.

Sub –question 3

Semi – structured interviews

The list of theoretical factors of influence needed validation to form an input for the draft of the NRL -scale. According to publications in the literature, the use of ***semi –structured expert interviews*** is the best method to validate. Semi-structured, qualitative interviews are the most appropriate way to capture the complex and multi-layer character of collaborations to change processes (Mattes et al., 2015). The interviews should be conducted with actors in a network, and need to give insights into whether the activities undertaken are adding to the network formation, or whether they form a barrier (Hekkert, Marko ; Heimeriks, Gaston; Harmsen, 2011). Interviews can be used to assess what influences development of new technology. It is impossible to evaluate an (innovation-) system based on quantitative criteria, due to the different characteristics of the technologies involved, the different regions, and actors. Qualitative expert interviews are needed (Hekkert, Marko ; Heimeriks, Gaston; Harmsen, 2011)

Sorting Exercise

Krijger used a ***sorting exercise*** besides ***semi –structured*** interviews to validate the list of factors in his works. The method of this sorting exercise was based on Q –sort methodology. In Q-methodology research, respondents are asked to rank a pre –determined set of factors, from high to low, based on the importance of the factor. The answers of the respondents are used to obtain subjective insights into the factors of influence on a collaboration (Exel & Graaf, 2005). The subjective answers of the respondents are based on '*the internal frame of reference of the respondent'*. The frame of reference refers to the role of the respondent, and is established based on his/her experience(McKeown & Thomas, 1988).

The set of factors presented in the Q –sort methodology originates from naturalistic sampling, or ready –made sampling of factors, done by the researcher. In the naturalistic sampling, the opinion of the respondents is used as a basis for the set of factors. Before the actual Q-sort, the opinions must have been obtained. The ready –made sampling is based on factors found in the literature on the topic of research(Gentles, Charles, & Ploeg, 2015; R & Rubinstein, 1995). During the Q-sort, the respondents are asked to rank all the presented factors to create an idea of the importance of all the factors relative to each other.

Validation Method used in this thesis

In this thesis, ***semi -structured expert interviews***, in combination with a ***sorting exercise*** were used to validate the lists of factors. Semi –structured interviews were used to gain an insight into the background of the respondent, and an insight into the opinion of the respondent on important factors of influence on a collaboration. Semi -structured interviews were used since questions drafted before the interview were included, but also subjects, and insights that came up during the interview could be addressed (van Teijlingen, 2014). The experts for the interviews were originating from the cases of Tata Steel IJmuiden.

After the semi -structure interviews, the experts were asked to fill in three ***sorting exercises*** to validate the lists of factors drafted in sub -question 2. One for the properties, one for the facilitators, and one for the barriers. The list of the properties existed only of the properties, where the lists of the facilitators & barriers were structured with coding classes. By using a sorting exercise the lists drafted in sub -question 2 could be validated based on a numerical value that was assigned by the respondent.

The method of the sorting exercise was based on the methodology of Q –sort, but was slightly changed. The sorting exercise of the facilitators asked experts to rank five factors from 1 to 5 in order of importance, instead of asking the respondents to rank all the factors that were presented. The sorting exercise of the facilitators & barriers asked to rank the coding classes in order of importance.This was done to make the task for the respondents easier. After ranking the coding classes, the respondents was asked to pick individual facilitators & barriers of influence, but not to rank these. The difference between the structure of the sorting exercises is presented in Appendix D.1.

The respondents were finally asked to give a motivation for the ranking they filled in during the sorting exercise. This caused a discussion to emerge on the factors of influence in a network of actors, which gave the experts the opportunity to express their opinion. The expert opinions could be used, besides the numerical outcomes of the sorting exercises, as an input for the draft of the NRL -scale, or could be used as an extra validation of factor.

The interviews were recorded (audio recorder) and transcribed in summary, after which they were sent back to the interviewees for validation. After the validation, the interviews were coded. Coding is needed for subdividing, as well as assigning categories to the data. Categories are tags or labels for allocating units of meaning to the descriptive information obtained in the study. The categories used for the coding have been determined before the start of the data collection, as was described by (Basit, 2003). A provisional 'start list' of codes was present as the 'coding classes' in the sorting exercise of facilitators & barriers. The coding classes used were: collaboration, communication, economy, technology, institutions, (and geography).

Case Study of Tata Steel Cases

Cases of renewable energy development at Tata Steel IJmuiden were used to find experts to conduct the interviews and sorting exercises with. Multiple cases were present, but a selection of cases was made due to time constraints, and the fact that not all cases consisted of a network of actors that formed the social dimension of a socio -technical system. The selection of the cases was made based on the following criteria:

- The case must have socio -technical characteristics; network of actors collaborating to develop, maintain, and manage a technical system, bounded by institutions.
- The case is a socio -technical project conducted in collaboration with external parties (TSIJ + External Actors)
- Both private and public actors are present in the case.
- The case concerns the development of a renewable energy project (waste heat is included).
- The case is conducted in a multi -actor network; meaning more than 1 actor, company, organization, etc. is involved.
- There is a heterogeneous role for all actors in the case; meaning the case could only be conducted through collaboration

The criteria were used to select the cases. The criteria made sure the actors in the cases had experience with collaborating in a network of actors. A preliminary list of case experts was drafted in consultation with my thesis supervisor at Tata Steel, based on their role in the different cases. Subsequently snowball sampling was used by asking the experts for more interview contacts during the interviews. Once the experts were selected, they were invited by sending them a cover letter, and the interview template. Finally, the semi –structured interviews and the sorting exercises were conducted to validate the lists of factors.

Sub –question 4

In order answer the fourth sub –questions, and main research question. The validated factors had to combined with the expert opinions to create the improved NRL -scale. In order to combine the factors and expert opinions in a structured way, a four -step analysis was used. This four-step analysis was drafted to be able to structure the large amount of data, and make sure all important factors were included. In the four -step analysis the outcome of each step served as an input for the next step. The outline of the analysis is presented in figure 2.2 on the next page.

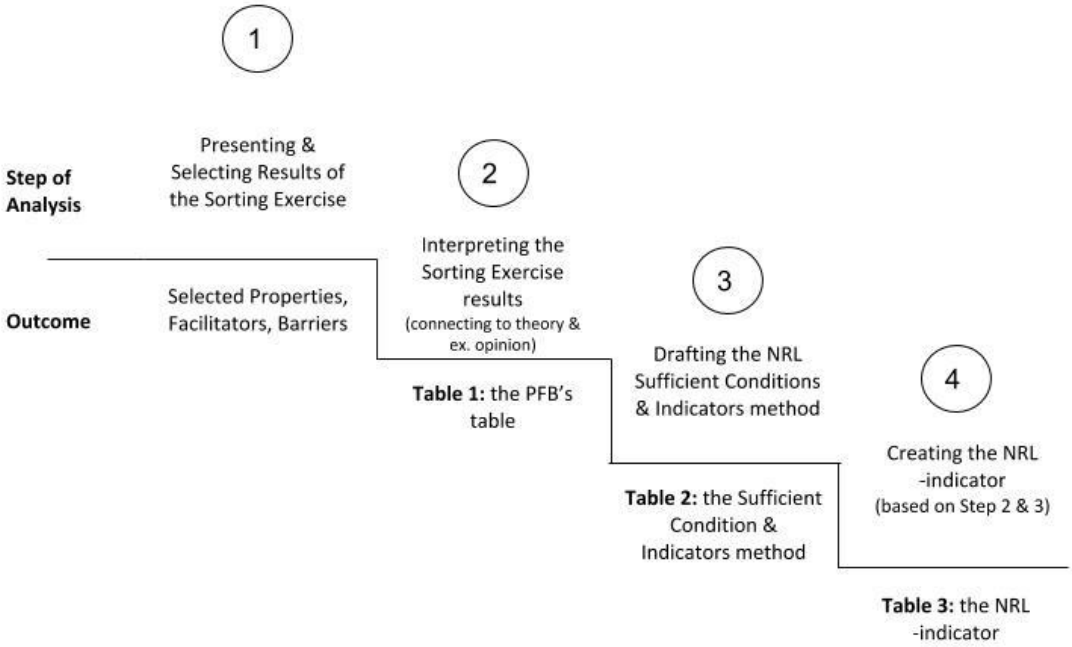

Figure 2.2 – The 4-step result analysis used to create the NRL –indicator. In each step (1 to 4), the action is presented on top, and the result directly underneath. For example; Presenting & Selecting the Results of the Sorting Exercise in step 1 leads to the selected properties, facilitators, and barriers. In this way the output of a step of analysis is the input for a next step.

In the first step of analysis, the results of the sorting exercise are presented. Besides this, the factors that were most mentioned in the sorting exercise are selected for further analysis. The properties, facilitators, and barriers are selected based only on the numerical value obtained in the sorting exercise. The result is a first selection of the most important properties, facilitators, and barriers of influence in a network of actors.

As a second step of analysis, the factors selected in step one are interpreted to see how they could serve as an input in the NRL -scale draft. The interpretation is done by connecting the selected factors to theory and to the expert opinions. This connection should provide a better understanding of the factors, and a motivation to include the property, facilitator, or barrier in the draft of the NRL. Besides connecting the factors to theory and expert opinions, extra PFB's that were not included in the sorting exercise are added in this step. The extra PFB's are selected from the expert opinions obtained during the interviews. The interpretation is finished by connecting the PFB's to a level of development in the NRL scale, combined with a motivation for the connection. The final result of the interpretation is Table 1. The table represents the most important PFB's connected to the different levels of development of the NRL -scale.

As a third step of analysis, the results of step two are translated into Sufficient Conditions & Indicators for each level of development on the NRL -scale. The outcome of the translation is Table 2. Table 2 presents the Sufficient Conditions & Indicators method to assess the readiness of the network of actors. The Sufficient Conditions & Indicators method is inspired by the method that Krijger created in his works on the NRL -scale.

As a fourth and final step of analysis, the NRL- indicator is created based on criteria that have to be present in a network of actors. The criteria are obtained from step two and three of the result analysis. The criteria are used to create a new methodology to assess the readiness of the multi - actor network; the NRL -indicator (Table 3). The NRL -indicator is the final outcome of the results analysis, and the answer to the main research question in this thesis.

Sub –question 5

In order to answer sub- question 5, the NRL -indicator is compared to the already existing NRL – scale of Krijger. The comparison should indicate the difference between the two methods, but also why the NRL -indicator is an improvement to the other methodology. The comparison of the new scale to the already existing one is done in discussion the new methodology proposed in this thesis in chapter 6.2.

2.2 RFD (Research Flow Diagram)

In the RFD, the flow of the research is shown, by presenting a summary of the research approach. In the RFD, a distinction is made between the Actions in the rectangles, and the Results of the actions in the circles. The chapter of this thesis in which a certain outcome or action is mentioned is presented by: Ch. X/Ap. X at the bottom right corner of the actions/outcomes. By introducing the distinction between the actions and the results, the different research steps are shown.

The flow of the research is as follows: A preliminary research starts at the analysis of the NRL of Krijger. This analysis lead to three results, which formed the starting point of the research; the insight that a weak Theoretical Framework (abbreviated as T.F in the RFD) was used in the works of Krijger, the need to look for properties, facilitators, and barriers in theory to conduct a research into the draft of a NRL –scale, and the idea of using an expert sorting exercise to validate the theoretical list of factors (the interview protocol). The weak T.F. in combination with a literature study lead to the draft of new theoretical framework in the left part of the diagram. The PFB's of Krijger in combination with PFB's from the literature lead to a theoretical list of PFB's. At the same time, the experts to conduct the sorting exercises were selected based on the case of TSIJ and the criteria for case selection. The list of PFB, the Interview Protocol, and the Experts formed the input for conducting Semi –Structured interviews and a Sorting Exercise at the right side of the diagram. This results in the validated list of PFB's in combination with the expert opinions. A four-step result analysis was used to change the validated lists of PFBs and the expert opinions into the final outcome of this thesis; the NRL –indicator.

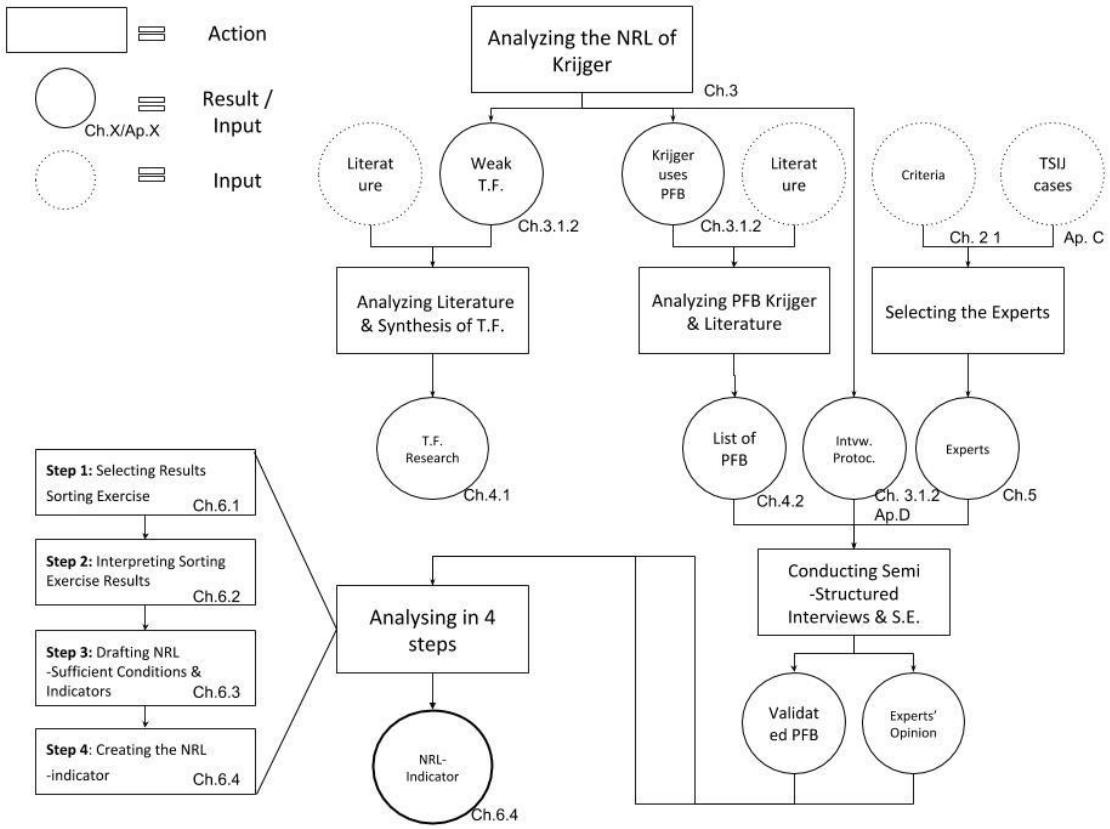

Figure 2.3 – Research Flow Diagram of this thesis.

Chapter 3

The NRL -scale

In Chapter 1.2; the Research Problem, some points of improvement in the NRL -scale of Krijger are already mentioned. In this chapter, the results of a study into the NRL -scale of Krijger are presented. The NRL -scale of Krijger is studied to form an example for this research, but also to find out whether there are points of improvement in the theory, and the methodology that Krijger used. At first the NRL – scale is introduced, as a second step the NRL is explained, and points of improvement are presented.

3.1 The Network Readiness Level (NRL) – scale

3.1.1 Introduction of Krijgers' NRL -scale

The NRL was first proposed in the MSc thesis of D.Krijger on collaboration for demand response in industrial clusters (Krijger, 2016)[1]. In his research, Krijger wanted to indicate the factors of influence on the collaboration. The NRL was proposed as a tool to indicate the readiness of the network of companies to adopt demand response in their business. Where the network was determined as the social dimension of the collaboration. In the development of the NRL, Krijger was inspired by the example of the already existing TRL (Technology Readiness Level).

The TRL is a scale, consisting of nine level of development (TRL 1 –TRL 9), developed by NASA to indicate the readiness of a technological development (Mankins, 1995, 2009). The development of a technology is indicated by assigning a TRL to the technology. For each level (TRL 1 – TRL 9) a condition is present. If a new technology meets the condition of a specific level, that level is assigned to the technology. By indicating the level of development on a scale, the communication about the readiness of a technology is facilitated through unification. The same image of technological development is created, facilitating 'stop -go' decisions, and collaboration between multiple actors. [2]

Krijger proposed two version of a NRL that consisted of seven levels of development (NRL 1-NRL7). In the first version (Table A), Facilitators & Barriers that characterized the levels of development were presented. The table showed the factors of influence on a network, connected to a specific level of development.Besides table A, Krijger drafted Table B with Sufficient Condition & Indicators for each level. This table could be used to really indicate the level of development of a network. The user of the tool could indicate the level of development by checking whether the condition of a level was met, supported by the indicators. The tool was proposed to capture the dynamic character of collaboration in a network on a numerical scale. More importantly, the works of Krijger presented a research method to find out what factors influence the development

[1] The Thesis of Krijger is not published publicly. Title: Assessing the Social Element in the Development of Socio Technical Systems: the Network Readiness Level

[2] The TRL – scale is further explained in Appendix B

of a network, and how these could be used to draft a NRL –scale. Before the value of the research method of Krijger is explained, the points of improvement in the NRL are presented.

3.1.2 The NRL –scale explained

Theoretical Framework of Krijger

The research of Krijger on the NRL –scale is based on a theoretical framework to stimulate innovation in a network by (Dhanaraj & Parkhe, 2006), supplemented by two own insights. The framework states that different actions could be undertaken by a central hub firm to leverage the innovative output of a collaboration in a network. The actions are referred to as orchestration processes that should be conducted by a network manager. Krijger basis his research on this one framework, and structures the potential factors of influence based on the five orchestration actions. The theoretical framework is rather thin to use in this thesis, and has a totally different scope. The framework looks at introducing innovation in a network, whereas in this research the social dimension of a socio -technical system is central. Different aspects of the NRL are therefore present in the works of Krijger that should be improved in this thesis.

Points of Improvement

The main motivation of Krijger to conduct the research was to propose a first draft of a new methodology. He used the TRL as an example, but no other publication on the topic of assessing the readiness of a network of actors existed. Krijger wanted to find out whether it was actually possible to draft a scale to assess the social dimension of an innovation network, therefore, there are some points of improvement present in his works.

At first, as was already mentioned briefly, the framework of Dharanaj & Parkhe aims at stimulating the innovative output of collaboration in a network of actors. In this thesis, the aim of the NRL -scale is to indicate the development of a small scale network of actors in a socio -technical system. The scope of the framework of Krijger is different from the scope of this research. The framework of Krijger, focusses on the management strategy a hub -firm, or network manager could use to align the network. The framework mentions five orchestration processes a manager could use, but surpasses the influence of important factors as: changing needs in the network over time, the impact of institutions, the impact of technology, and the role of different actors in the network. The framework used by Krijger is not elaborate enough to describe the development of a network of actors, because it surpasses these factors of influence.

Besides, the framework of Krijger does not say anything about the process of development of a network, while the aim of his research is to draft a numerical scale that is capable of indicating a level of development. In the framework of Krijger no phases, stages, or levels are present that indicate a process.

As a final point of improvement, the framework Krijger does not make a distinction between public and private actors, because the researcher did not interview public actors in his research. In a project adding to an existing socio -technical system this distinction needs to be made, due to the important role of public actors.

Based on the mentioned reasons, the theoretical framework of Krijger is not applicable in this research. A more elaborate literature study is needed to develop a new theoretical framework to structure the development of a network of actors.

Research Methodology of Krijger

Krijger on the other hand, did propose a suitable research methodology to find out what the most important factors of influence on a network of actors are. As a first step Krijger conducted a literature study into the factors of influence on a collaboration for stimulating innovation in a network. He structured the outcome of this literature study in a list of ; properties, facilitators, and barriers of influence. After compiling the lists, Krijger conducted semi -structured expert interviews in combination with three sorting exercises to validate the lists.[3]

The most chosen properties, facilitators, and barriers during the sorting exercise, formed the input for a first table (A). The table consisted of the Facilitators & Barriers that came forward during the sorting exercise, connected to a level of development. To assign a facilitator, or barrier to a level of development, remarks made by respondents were used. The Facilitators & Barriers table could be used to indicate the factors of influence on an innovation network, but was not suitable to indicate the level of development of a network of interest.

To indicate the level of development, Krijger presented Sufficient Conditions & Indicators for each level of development. The Sufficient Conditions & Indicators method is derived from the TRL, in which all levels have a requirement that has to be met to assign a TRL to the technology. The state of the network is determined, based on the highest NRL for which the network meets the sufficient condition. If the sufficient conditions of NRL 3 and NRL 5 are met, NRL5 is assigned to the network. NRL 3 is expected to have been reached before, since the sufficient condition of NRL 5 is met. The method allows for the precise indication of the NRL based on the fulfilled sufficient conditions. Indicators are presented in each level of development to support the decision. Based on the Sufficient Conditions & Indicators method, Krijger presented a second table; Table (B), that could be used to assess the readiness of the network. The Sufficient Conditions & Indicators were based on the interview results, and the Facilitators & Barriers of table (A).

The steps of Krijger to first conduct a literature study, then validate the outcomes by using an expert sorting exercise, then structure the validate outcomes in Table A first, Table B second, are valuable. This research methodology is adopted in this thesis.

3.1.3 Concluding remarks on the NRL –scale of Krijger

The work of Krijger uses a theoretical framework with a different scope, than this research uses. Besides this, the framework of Krijger does not include factors of influence on the development of a network, does not include the idea of a process of development, and does not include public actors in the research. These four reasons motivate the need to create a new theoretical framework on the development of a network of actors in a socio -technical system. On contrary to the theoretical framework, the research methodology used by Krijger is valuable in the draft of the NRL -scale. Krijger used a pre –determined list of factors (properties, facilitators, and barriers) that were validated through a sorting exercise and semi –structure interviews with experts. The analysis of the NRL of Krijger leads to the insight that two literature studies are needed. At first, a literature study into the draft of a new theoretical framework, followed by a literature study to determine the list of properties, facilitators, and barriers to be validated by the experts.

[3] See Chapter 2.1 (Sorting Exercise) & Appendix D.2 for an explanation of the sorting exercise.

Chapter 4

Literature Study

In the previous chapter, a study of the works of Krijger showed the need for two separate literature studies. One into the draft of a new theoretical framework, presented in paragraph 4.1. The other literature study to compile lists of properties, facilitators, and barriers for a sorting exercise, presented in paragraph 4.2.

4.1 Creating a new Theoretical Framework

At first the scope, and understanding of a network used in this research are presented. This is needed, because the understanding of a 'network' could be very different in different contexts. After the scope and understanding are clear, the theoretical framework to structure the development of a network of actors can be drafted.

4.1.1 Introducing the meaning of a 'Network'

The scale of the Network

The multi -actor networks studied in this research, aim at creating a contribution to a socio – technical system by working together. The contribution is not created in the form of a new technology, but in the implementation of an existing technology, adding to a socio -technical system. In order to understand the scope of the research, at first the meaning of a ' socio -technical system', needs to be explained, supplemented with the meaning of a 'multi -actor network'.

In socio –technical systems, technical artefacts are embedded in a social network of actors (Nikolic, 2009; Thakker, Yang-Turner, Lau, & Dimitrova, 2011). The socio -technical systems are the interplay between humans, organizations, and technical systems (Dalpiaz, 2013). In a description of these systems, both the technical artefacts in the technical dimension, the actors in the social dimension, as well as the connections within and between these dimensions, needs to be included (Bas, n.d.). The systems emerge because of the activities of the actors, such as the exchange of knowledge, and resources. The systems aim to fulfil societal actions, such as communication, transportation, energy supply (Smith, Stirling, & Berkhout, 2005). The scope of the system is, however, too big for this research, since it looks at the development of whole systems fulfilling societal functions. The multi -actor networks as described in this research, exist to add to this system as a whole, but the scope of the network is smaller.

Van der Lei places the system, network, and agent level in respect to each other to show the difference between the three levels. The complete system consists of three levels in his complex adaptive system theory; the agent level, the network level, the system level (van der Lei, Bekebrede, & Nikolic, 2010). At the lowest level; the agent level, individual entities, or agents are presented. The agent is influenced by its environment (other agents), called its *input*, and influences the environment through its *output* (Bas, n.d.). The agents are, however, individual entities not connected to each other. At the network level, the agents are connected in a network by their interactions. The agents are represented by *nodes*, and the interactions between the different nodes are represented by *edges*. If nodes are connected it means that the actors are in some way influencing each other in the network through an interaction (Håkansson & Ford, 2002; Lawyer, 2015). At the highest level; the system level, the behaviour of a system as a whole, coming forward from the networked interactions between agents, is described. The system as a whole functions within its environment, which on its turn influences the systems behaviour (Bas, n.d.).

The network level is placed in between the individual agent, and systems level. The network consists of actors that are connected through their interactions. This explains the scope of the network, but in a very theoretical description. No insight is given into what the network does, how the network develops, or what the interactions produce. This needs to be researched further.

The Understanding of a network of actors

Multi -Actor Networks represent the knowledge exchange, resource exchange and negotiation among independent actors (Newell, Sandström, & Söderholm, 2017). The interactions are aimed to produce different outputs, depending on the background of the network. The network could for instance exist out of organizations to develop new technologies and innovation (Corsaro et al., 2012; Hekkert, Marko ; Heimeriks, Gaston; Harmsen, 2011). The network could be based on the integrated approach by relevant actors in the network to pursue sustainable development (Devine-Wright, Fleming, & Chadwick, 2001)**,** or pursue the pure economic goals of the actors involved in the collaboration (Hwang & Seruga, 2011)**.** A network could simply exist because a problem cannot be solved by one organization, but could be solved by a network of organizations working together (Agranoff & McGuire, 2001).

Independent actors in the network could be different; companies, organizations, individual actors, governmental organizations. As long as they are connected, and are relevant for the understanding of the network, they could be seen as part of the network (Håkansson & Ford, 2002; Haythornthwaite, 1996). The networks are influenced in their functioning by the specific technological area, different institutions, and the competence flows between the different actors in the network (Jacobsson & Johnson, 2000). In a socio -technical system, the network of actors represents the social dimension of actors, companies, organizations responsible for developing, maintaining, and managing the technical system (Moncada, 2017).

In the previous paragraph the scope of the network is presented as the middle level of a socio -technical system, between the individual agent level, and the system level as a whole. In this paragraph the network is presented as an interaction of different actors, companies, or organizations representing the social dimension of a socio -technical system. Based on these two description the multi -actor network as used in this thesis could be seen as the social dimension of a socio -technical system at a lower level of analysis. The network of actors works together to contribute to the larger scale socio -technical system. The meaning of a network of actors in this thesis, based on the previous statements could be seen as: '***a collaboration of different actors, that develops, maintains, and manages the technical system of a socio -technical system at a lower level of analysis'.***

To give an example of the scope of the research. The development of a wind park adds to the larger energy system, and is developed, maintained, and managed by a network of actors at a lower level of analysis. This is the scope that is aimed for in the development of the NRL.

4.1.2 Drafting the Theoretical Framework

The understanding of a network of actors in this thesis is explained in the previous section. In this paragraph a new theoretical framework to structure the development of a multi -actor network is proposed. The motivation to create a new framework is given in paragraph 3.1.2. At first, different theories are discussed to look for useful insights from literature. As a second step the different theories are combined to create a new theoretical framework.

Network Development

In the 'Innovation Network' theory, a framework to structure network development is proposed. The framework introduces a hub firm that should leverage the output of the network. The firm does this by taking the design of the network into account in its actions to orchestrate the network. The network design consists of three parts; the network membership (the actors involved), the network structure (the relation between the actors), and the network position (the relation to other networks) (Dhanaraj & Parkhe, 2006). The approach of looking at the network design is further shown by the idea that a researcher should first determine four things in the network; the actors, the institutions, the structure, and the technological factors present in a network, before one is able to understand the innovation network, and make decisions on the development (Hekkert, Marko ; Heimeriks, Gaston; Harmsen, 2011).

A different theory on Network Management, describing public networks of actors, proposes strategies aimed at three characteristics of the network; the structure, the substance, and the process (Newell et al., 2017). In which the structure is determined by the actors involved and their relations. The substance is presented by the content and goal of network development. The process is determined by the interactions within the network leading to the creation of the network. Deliberate attempts to manage collaboration in networks are aimed at these three characteristics. (Koppenjan & Klijn, 2004; Newell et al., 2017). The Network Management theory is divided in an institutional approach, looking to change the fundamental rules influencing the network, and a process design approach, aimed at influencing the design of the network without changing the underlying rules

The institutional angle of the Network Management theory, uses 7 types of institutions, obtained from the IAD-framework of Ostrom, that shape the collaboration in a network. The network is put centrally, and the potential influence of the institutions on the networks' structure, process, and substance is researched (Newell et al., 2017). The process design approach in the Network Management theory looks at how four specific managerial approaches could be used to influence the networks' structure, substance, and process: (1) the activation of actors, (2)the use of goal-achieving strategies, (3)the creation of incentives and (4) the removal of obstacles(Koppenjan & Klijn, 2004). In this process design approach, more emphasis is put on the actual creation of networks, and what could be done to structure the network (Klijn, 2005).

In both theories points of focus are used to structure the network development. The points of focus of the Network Management theory are the starting point in this thesis to understand which factors are influencing a multi – actor network. The focus points, from this point on called the network characteristics are used as a first outlined of the theoretical framework. The Network Structure, Network Substance, and Network Process are connected, and presented in figure 4.1 in the orientation of a triangle.

The representation of the network characteristics, however, is not enough to represent a framework for network development, because of three reasons:

(1) The triangle of figure 4.1 only represents the outline of the framework by representing the characteristics as spheres, but does not provide further explanation.
(2) The right orientation of the triangles is not known yet. The triangular orientation is used, based on assumptions. The orientation of the characteristics needs further research.
(3) Three characteristics are presented, but it is not sure whether more characteristics need to be added, or characteristics have to be removed.

Because of the three reasons mentioned, a more elaborate literature study is conducted into the three characteristics, starting with the Network Process.

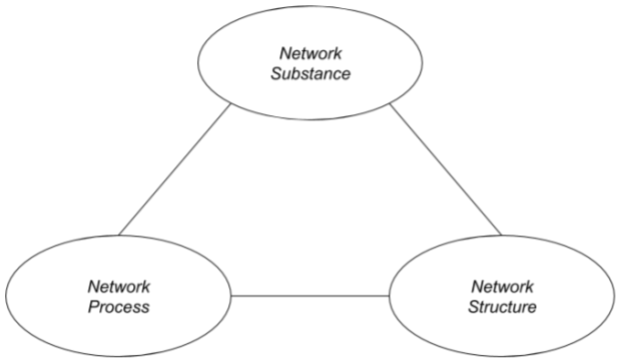

Figure 4.1 - The three characteristics of network development represented as connected spheres, without further details on what the characteristics entail

Network Process

The network process is determined by the interactions between the actors leading to the development of a network (Newell et al., 2017). Different studies describing the development of a network see the development process as a stepwise process through phases of development. For the implementation of renewable energy in a network, a three step process was introduced: (1) problem formulation, (2) mobilization, and (3)communication (Mårtensson & Westerberg, 2007). A region aiming to become energy autarkic presented a similar process in five steps for the development of the network of actors (Müller, Stämpfli, Dold, & Hammer, 2011). Another study showed the development of energy self -sufficiency in a region divided into 4 stages of development (Hecher, Vilsmaier, Akhavan, & Binder, 2016). In the field of project management, a project is conducted by actors in five standardized phases of development. To structure the development of renewable energy projects, a process consisting of two phases with multiple steps of development in each phase exists (Springer, 2013). The different studies hereby structure the process as a **stepwise process** of development, going through multiple stage of development. They, however, only present the stepwise process, and do not clarify what factors influence the development of the network over time.

Other publications do try to connect the influencing factors to the stages of development. A first method to do so is presented by Ruppert –Winkel. She proposes a division of the development process into three phases: pioneer phase, pivotal network phase, extended network & market phase. Beside these phases of development, different elements of the network; such as the outcome that is created, the actors and their activities, and the actor motives are introduced. The method follows the elements throughout the phases of development, and tries to connect the elements to the phase of development in which they are influencing the network development (Hauber & Ruppert-Winkel, 2012; Ruppert-Winkel, Hussain, & Hauber, 2016).

A different approach is presented in Hekkerts' Functions of Innovations theory for innovation networks. The theory proposes an approach in which four phases of development are stated first. After the four phases, 7 functions of innovation systems are presented that have to be present at the end of the network development to stimulate innovation. Each phase has specific functions of systems that are important in that phase of development, showing the presence of different functions throughout the development process (Hekkert, Marko ; Heimeriks, Gaston; Harmsen, 2011). The approach turns around the method of Ruppert -Winkel, by stating a stage of development first, and identifying the functions of systems that are important in the stage. Instead of following an element throughout the stages of development.

The approach of Hekkert shows that different functions are needed in different phases of development, depending on the actions needed in that specific phase. The functions are therefore used to describe, and indicate the dynamics taking place in each stage of development (Hekkert et al., 2007). The method even provides the option to assess which functions are met, and which are not to indicate what functions hinder the further development of a network (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008; Hekkert, Marko ; Heimeriks, Gaston; Harmsen, 2011)

The idea of **changing factors influencing a development process over time** is supported by (de Bruijn, Hans; ten Heuvelhoff, Ernst; in 't Veld, 2006). De Bruijn states in his works that the changing character of a process, or a project over time leads to a change of approach that has to be taken. The approach needs to change from a more project managerial approach to a more process managerial approach. It is not the change of approach that makes his theory interesting, but more the idea of the changing factors over time influencing a development process.

In his works, the factors influencing the development over time are presented by external and internal dynamics. The external dynamics are caused by external actors, influencing the process with their own interests, ideas and solutions, whereas the internal dynamics are caused by internal actors. The idea that the project, or process is different from their expectation, leads to a change in the approach of the internal actors. In this theory the process of development is put centrally, and both internal and external factors are influencing the process over time. This is related to the ideas of Ruppert-Winkel, and Hekkert, who propose that the development process is influenced over time by different factors. De Bruijn, however, does not include phases of development to his theory. Figure 4.2 is presented to clarify the influence of external and internal dynamics.

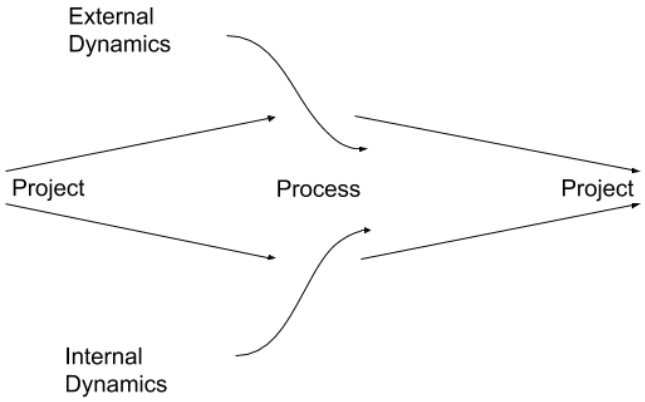

Figure 4.2 – Graphical representation of the theory of de Bruijn in which Internal & External Dynamics could change the need of a project management design to a process management design. The important insight from the theory is that factors of influence on a development process, change over time, changing the management approach needed.

The three theories show that different interactions in the network, whether this is between actors, or with outside factors, influence the development over time. The publications on the Network Process by Hekkert, Bergek, Spath, De Bruijn and Ruppert – Winkel, use the rather vague name of stages, or phases of development for the different stages of network development. Each publication connects factors of influence to a stage of development. There is, however, no publication present, to the author's knowledge, besides the thesis of Krijger, which connects a level of development to a network to assess its readiness. The absence of publications shows a gap in the literature on network development that could be filled by this thesis. A table in Appendix F, summarizes the content of the different theories. The theories only place the development process (Network Process) centrally in the form of a stepwise process, influenced by changing factors along the process. This orientation is adopted in this study. The factors of influence need to be determined in the next sections.

Network Structure

After presenting the first characteristic of network development in previous paragraph, the second characteristic of network development; the network structure, is presented. The network structure consists of **the actors in the network**, and their **connections** (Dhanaraj & Parkhe, 2006; Hekkert, Marko ; Heimeriks, Gaston; Harmsen, 2011; Newell et al., 2017). Supplemented with the actors that could potentially influence the network, since the ability to influence the network development makes an external actor a stakeholder in the network (Devine-Wright et al., 2001).

Actors are acting strategically as individuals, as part of a group, or as an organization supporting different **roles in the collaboration** (Corsaro et al., 2012; de Haan & Rotmans, 2018). Different examples of these roles are provided in literature. The Front Runner of the network makes new ideas presents, and acts on its own or driven by company values to facilitate the network. In order to combine actors in the network, a Connector is needed. This actor connects the actors in a network based on shared set of values and opinions. The Topplers take the role of promoter of the network, acting as the facilitators, and public lobbyists of the networks. By articulating the value of the network to others, they are able to attract followers. These followers are the supporters of the network, supporting the new solutions of the network, and more importantly adopting the solutions. This distinction in four roles gives a rather theoretical perspective of the actor roles in a network, and asks for a more practical explanation.

The Frontrunner and Connector role can be taken on by the central orchestrating actor in the network. The Central Coordinating Actor functions as an important initiator, and a link between different actors within the network (de Haan & Rotmans, 2018; Newell et al., 2017; Späth & Rohracher, 2010). The actor could both be an internal actor, coming from one of the groups, or organizations in the network, or an outside actor appointed to perform the role. His role is to facilitate a collaboration, and combine different actors in a network (Pikkarainen, Ervasti, Hurmelinna-Laukkanen, & Nätti, 2017). The Toppler role could be taken by the process manager, who makes sure all deadlines are met, and the whole process is successfully finished within time, and budget (Bohoris, 1994). The role of supporters could be taken by the external actors influenced by the output of the network (Devine-Wright et al., 2001).

The connection between the actors in the network is made by sharing knowledge and resources, through **communication**. Too weak interactions caused by too little communication leads to a lack of knowledge diffusion, and thereby no learning by doing in the network (Negro, 2007). Personal relations between actors leads to improved communication (Ambrose, Eadson, & Pinder, 2016). The method of communication is not important, as long as the communication is done; effectively, efficiently, and frequently by choosing a clear method (James E. Austin, 2000; Turner & Müller, 2004).

Besides the communication between the actors, the meaning behind the communication from an actor's perspective, is also influencing the development. Willingness to cooperate in a network is presented as influencing the development of the network (Ipe, 2003). The reluctance to share resources among the actors in the network, and a 'what's in it for me attitude' when entering the collaboration are hindering factors in the network (Lutz, Lang, & von Wehrden, 2017b; Newell et al., 2017). Lack of trust in the network, or previously broken agreements are typical other factors hindering the collaboration(Newell et al., 2017).

Actors on the other hand, should understand what the goals of the network are, and should be willing to share resources to work towards a stable collaboration(Lutz, Lang, & von Wehrden, 2017a; Newell et al., 2017). By these actions, the actors show commitment to the network and an understanding that working together in a network is the best option to achieve output from the network (Ambrose et al., 2016; Mårtensson & Westerberg, 2007). The mentioned factors are summarized under the theme of **collaboration,** since the factors influence the actual collaboration part of the network.

To summarize, the network structure consists of the actors involved in the network, and their interactions. The actors influence the network development by the role they play in the network. The interactions between the actors are influenced by the means of **communication**, but also by the **collaboration** factors in the network.

Network Substance

In this paragraph the network substance is presented. The network substance is anything that is present in, or influence the network, but the actors. The network substance consists of the external factors and the internal factors influencing the development process (de Bruijn, Hans; ten Heuvelhoff, Ernst; in 't Veld, 2006)**.** The substance differs from the network structure since the content is not necessarily related to actor interactions in the network, but related to internal factors, related to for instance; **technology, economy/financial,** or the **goal** of acting in a network (Painuly, 2001). Besides this, the external factors such as the **surroundings**, and **institutions,** that influence the network development. The different internal and external factors are introduced briefly in this paragraph.

The goal of the collaboration is created based on the different technological, and economic aims of the network, but also the values and interests of the different actors involved (Lutz, Lang, et al., 2017a). The goal of the network influences the development of the network, since it determines why the actors are together in the network in the first place (Sandstrom, 2015). Different interests of the actors determine the individual goals of a collaboration. A common goal, however, should be pursued among the actors to make the network a success (Zuppa & Issal, 2008). Aligning of interests, and a shared vision help to pursue a common goal (Newell et al., 2017).

The **technology** determines how the social dimension, and technical dimension of the socio -technical system are connected. In the Actor Network Theory, technology is even considered an actor in the network, since interactions between the actors and technology take place, and actors and technology are connected (Latour, 2017; Twum-Darko & Harker, 2017). In the socio -technical systems view, the technology is embedded in a social system as a result of the interaction between actors. The network of actors tries to add to the technical system (Moncada, 2017). The latter view is used in the research. The type of technology concerned, and the level of development of the technology influence the network of actors (Ambrose et al., 2016; Newell et al., 2017). If the technology concerned is still developing, the network is aimed at trying to develop the technology further and overcoming technological hurdles (Hekkert et al., 2007), whereas the implementation of an existing technology requires a different approach within the network.

The **economic** factors of influence on the network entail the division of costs, and benefits, and the profit of the collaboration in a network. Economic circumstances are influencing the success or failure of network development (Lutz, Fischer, Newig, & Lang, 2017; Späth & Rohracher, 2010). A positive business case for the collaboration, and a potential profit are driving a collaboration. Lack of investment budget, and the absence of investors are hindering network development, because they threaten the feasibility of the project (Lutz, Fischer, et al., 2017)

The **environment** of the network is the total of actors, their interconnections, and institutions that are not directly part of a network (Choi, Dooley, & Rungtusanatham, 2001)**.** This is supplemented with the technological environment in which the output of the network is implemented. The environment influences the development of a network, because the network is always related to other networks, technologies, and actors outside the network (Newell et al., 2017).

The **institutions** concerning the network are influencing the development by two types of institutions. At first, by hard institutions in the form of rules & regulations, and legislation. The soft institutions such as culture, and manners, are the other type of institutions (Jacobsson & Johnson, 2000). Legal constraints in the form of long term administrative processes, changing political priorities, and changing law and regulations can negatively influence network development (Lutz, Fischer, et al., 2017; Newell et al., 2017). Changing subsidy schemes, contradicting institutions on different levels of policy, potentially causes uncertainty in the network (Späth & Rohracher, 2010).

To conclude the network substance can be divided into two parts. The internal factors of influence on the network development; goal of the network, technical and economic factors. Besides, this the external part; the environment, and the institutions.

A Fourth Characteristic; the Network Scale

Previously, the three characteristics of network development were explained by filling in the characteristics further by the different themes. During the literature study, a fourth characteristic of network development came forward; the Network Scale. This characteristic looks at the factors coming forward from the relatively small scale of the networks, studied in this research. The network level is tucked between the actor level and the system level in the CAS framework (van der Lei et al., 2010). The Network Scale determines the scope of the research, which has been overlooked so far. Networks could for instance exist on a worldwide scale, when looking for supply -chain networks consisting of multiple actors (van der Lei et al., 2010). On a lower level, the understanding of a region is used as a geographical boundary for a network of actors. The border of the region determines the network of actors in that case (Hauber & Ruppert-Winkel, 2012; Lutz, Lang, et al., 2017a; Ruppert-Winkel et al., 2016).

The advantages of being close together, having personal relations, and approaching problems on a low scale are some of the advantages that are mentioned of working together in a small network(Lutz, Lang, et al., 2017a; Lutz, Fischer, et al., 2017). Innovation clusters are expected to produce more output by having more knowledge on innovation close by (Schilling & Phelps, 2007). An example is the theory on Regional Innovation Systems (RIS). This theory endorses the importance of a smaller scale of networks, which are not limited by geographical boundaries; "*RIS can be seen as systems in which firms and other organisations are systematically engaged in interactive learning through an institutional milieu characterized by embeddedness"* (Cooke, 1998). Innovation for renewable energy development in a RIS is influenced by institutions, local/regional organizational networks, and materiality (the physical conditions surrounding the RIS) (Laurentis, Pearson, & Eames, 2016)

Considering the publications, the spatiality of the network is important to indicate the boundaries of the network. The spatiality does not provide structure to the research, or necessarily influences the development of a network. It determines the scale of the network.

Change of the Network Development Outline

Based on the theories found in literature, the outline of the framework as presented in Figure 4.1 could be change. In the literature on the Network Process, the notion emerges of a stepwise network development process that is influenced by different factors over time (Bergek et al., 2008; de Bruijn, Hans; ten Heuvelhoff, Ernst; in 't Veld, 2006; Hekkert, Marko ; Heimeriks, Gaston; Harmsen, 2011). The network develops over time, and is influenced by factors in each stage of development, coming from the Network Structure and the Network Process. The factors from the characteristic of Network Structure can be summarized in themes of; the actors in the network, and their interactions, the communication among the actors, and the collaboration among the actors. The Network Substance is filled in with the internal economic factors, technical factors and goal of the network. Besides this, the external factors of the environment and institutions. The final characteristic that was added, the Network Scale, determines the scope of network.

The description of the different characteristics creates the insight that the triangular structure of figure 4.1, needs to be changed to a structure in which the Network Process is positioned centrally, and the factors from Network Substance, and Network Structure, both influence the development of a network over time. The Network Scale is used as the boundary of the network. Figure 4.3 presents the outline of the framework, after the change in orientation is made. The structure still only represents the outline of the framework.

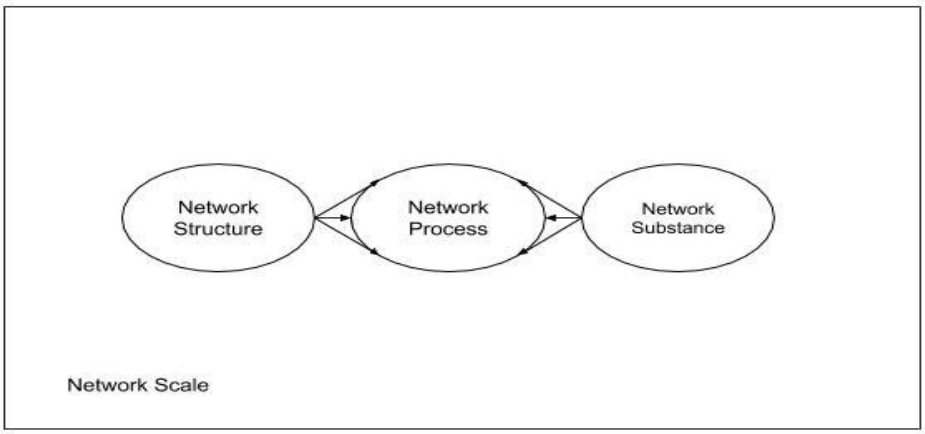

Figure 4.3 – The representation of the relation between the characteristics of network development, based on the insights from literature. The Network Scale forms the outer boundary, thereby presenting the scope of the research. The Network Process is presented centrally, with the factors from the Network Structure, and the Network Substance influencing the process.

4.1.3 Presenting the Theoretical Framework

In the previous paragraph the new outline of the theoretical framework was presented. As was stated before, only the outline is presented, without further content of the framework. The different themes determined in the literature study form the content. The themes were presented in **bold** in the previous paragraphs. The content is connected to the characteristics to create the theoretical framework of this thesis. The four characteristics of network development, and the themes that were determined in the literature study are summarized in figure 4.4.

Characteristic	Themes
Network Process	Stepwise Influencing over time
Network Structure	Actors, Roles of the Actors Communication, Collaboration
Network Substance	Internal (Technology, Economy, Goal) External (Environment, Institutions)
Network Scale	Scope of the Network

Figure 4.4 – Summary of the network characteristics, and the factors from each characteristic that are influencing the network development.

The theoretical framework of this research is represented in figure 4.5 on the next page. In the theoretical framework, the Network Process is presented as a stepwise process, consisting of 4 stages of development. Each stage of development is influenced by factors coming from the Network Structure, and the Network Substance, the two ovals on the left and on the right on the Network Process. These characteristics are filled in with the themes of influence that were determined in the literature study; the rectangles connected to the ovals. The factors of influence are represented by the overall themes of influence (summarized in figure 4.4). The whole process of development is bounded by the final characteristic; the Network Scale.

The theoretical framework is an outcome of the literature study to provide a theoretical background for the creation of the NRL -scale. The framework provides insights in the development of a network of actors. The most important insight is the fact that the development of a network takes place in a stepwise process, with different internal and external factors influencing the development over time. The draft of the NRL -scale adds to the idea of this stepwise process, but provides a more concrete idea of the development by presenting a numerical scale. In order to draft the NRL -scale, the factors of influence on a network of actors need to be determined.

The theoretical framework provides the coding classes for the sorting exercises. The sorting exercises are used to determine the factors of influence on a network. The following themes that are presented in the theoretical framework serve as the coding classes in the Sorting Exercises; *communication, collaboration, institutions/political, technology, and economy*. The coding classes structure the sorting exercise, and should make the choice of factors easier. The research methodology (sorting exercise), and the theoretical framework (coding classes) are thus combined to form the sorting exercise. The input for the sorting exercises, however, is not obtained in the draft of the theoretical framework. In order to determine the input of the sorting exercises a separate literature study is conducted.

A final remarks must be made on the theoretical framework. The framework is only a first version and needs further validation to determine the true value of the framework for further research. The framework was therefore not presented as an input for the research in the RFD in chapter 2.2.

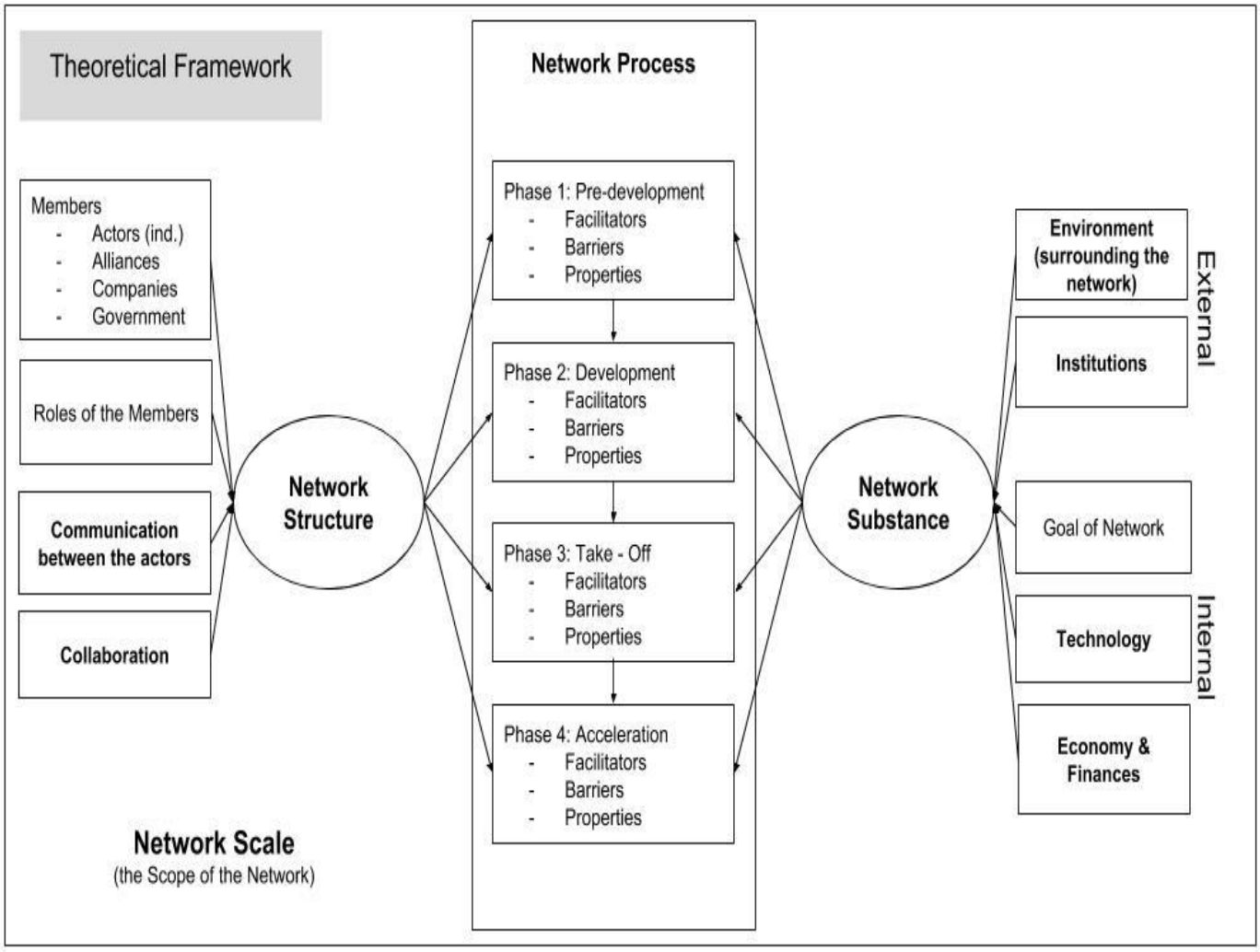

Figure 4.5 – The Theoretical Framework of Network Development. The four characteristics that were determined in the literature study, are filled in by connecting them to the factors of influence. The Network Development framework is connected to the NRL Development Process, to show the connection between the network and the structure of the NRL.

4.2 Introducing the factors for the Sorting Exercise

In paragraph 3.1.2 the idea of using three lists of factors to determine the factors of influence on network of actors was introduced. A list of properties, a list of facilitators and a list of barriers that need to be validated during expert interviews. In the previous paragraph the new theoretical framework was presented, providing the coding classes to structure the lists of factors. In this paragraph the lists of factors are drafted based on a desk research into the works of Krijger, supplemented with the results of a literature study. The lists of factors are presented in three different tables, including the sources that mentioned the factor. If no source is presented, the factor is included based on the general idea of the factor having an impact. The factors are selected based on their occurrence in the literature, therefore the combination of the factor and its source is used. The Sorting Exercise that was based on the factors is presented in Appendix D.3.

4.2.1 The Properties

The list of properties for the sorting exercise is presented in figure 3.6. The properties are the factors that have to be present in the network to collaborate. A brief introduction into the property is presented based on the information found in the source. If no explanation is provided, no information was present. The list of properties is not structure by coding classes.

The list of Properties as an input for the Sorting Exercise

Property	Source	Property	Source
Presence of CCA; the CCA should connect actors, and function as a point of contact in the network.	Krijger (Newell,2017) (Koppejan & Klijn, 2004)	**Like Minded Actors;** like -minded actors share a vision in the collaboration, which should facilitate the collaboration.	Krijger
Shared Vision; shared vision leads to trust, and the same idea about the result of adding to the technical system.	Krijger (Nahapiet & Ghosal, 2017)	**Institutional Framework to stimulate collaboration;** the institutional framework should clarify and structure the development by rules & regulations, creating clarity in the development.	(Lutz, 2017) (Newell, 2017)
Multi – level collaboration (local, regional, national); collaboration on different levels should lead to a smoother process, combining actors of different scales of policy.	(Newell, 2017)	**Declaration of Intent;** a declaration of intent is the first formalization of a collaboration, and functions as a milestone In the process.	General Idea
Actor Heterogeneity; actors supporting different roles should work together, due to the many different tasks in the development.	(Lutz, 2017)	**Formal Contracts;** formal contracts are the outcome of the development and are needed for structure, and formalization of trust.	(Poppo & Zenger, 2002) (Czernek, 2017) (De Bruijn, 2010)
Trust; trust is key in the development, and a starting point of further collaboration. A trusted partner makes sure all information is made present, and resources are shared.	Krijger (Vangen & Huxham, 2003)	**Transparency;** transparency shows that the other partners share all information and have the same motivation to participate.	(Nielsen, 2004)
Formal Relationships; relations between different actors on a professional basis.	Krijger	**Reliability of Actors;** the reliability depends on the performance of the actors shown during the collaboration.	(Weick, 2004)
Informal Relationships; possibility of collaborating based on friendship, and good relations.	Krijger		

4.2.2 The Facilitators

The list of facilitators in the sorting exercise is presented in figure 4.7. The facilitators are the factors of influence that will facilitate collaboration. The presence of these factors will help the development further. A brief introduction into the facilitator is presented based on the information found in the source. If no explanation is provided, no information was present.

The List of Facilitators as an input for the Sorting Exercise

CC	Facilitators	Sources	CC	Facilitators	Sources
Communication	**Alignment of Interests;** aligned interest cause the same goal to be pursued by actors, facilitating the development.	Krijger (Newell, 2017) (Ponti, 2010)	Collaboration	**Presence of CCA;** see property of the CCA present.	Krijger (Newell, 2017) (de Haan & Rotmans, 2018)
	Convincing plans; publishing convincing plans leads to clarity, by providing a goal.	General Idea		**Willingness to share resources;** makes the resources present in the collaboration, facilitating the further development	(Newell, 2017) (Lutz, 2017) (Ramim & Lichvar, 2013)
	Set Targets and Goals; help in determining the final idea of the development, and structure the collaboration.	(Lutz, 2017)		**Collaboration on different levels;** see property of multi –level collaboration.	(Newell, 2017)
	Presence of Milestones; present structure, and dots on the horizon.	(Lutz, 2017) (Späth, 2010)		**Presence of Key Actors;** taking a leading role, supporting the development actively.	(Lutz, 2017) (Späth & Rohracher, 2010)
	Communication Agreements; provide overall structure by agreeing on way and frequency of communication.	(Mattes, 2015) (Lutz, 2017) (Austin, 2000)		**Relationships at the beginning of the development;** could lead to actors finding each other more easily, and present trust from the beginning.	(Ambrose, 2016)
				Necessity to work together; the development has be done together, because alone is not possible, due to expertise, financing, core business etc.	General Idea
Political	**Institutions guiding the development;** the presence should drive the development, and create favourable conditions for the development.	(Newell, 2017) (Lutz, 2017)	Economic	**Financial Gains;** functions as a starting point by the possibility to gain a profit by conducting a project/development/collaboration	Krijger
	Subsidies; needed as the incentive to start the development, and provide part of the financial support.	(Lutz ,2017) (Hecher, 2016)		**Shared Risks;** should lead to the idea of divided risks in the development, triggering actors to participate, and to commit.	Krijger
	Support by decision markers; supporting decision makers create a level playing field, since the politics will support the development, which facilitates the process.	(Lutz, 2017)		**Investors in the project**; forms the financial background of the development, and the certainty on the financial side.	(Lutz, 2017)

Technological	**Related to everyday practices of the company;** the technology is expected to be implemented easier in the company.	General Idea	Geogrpahy	**Proximity of Actors;** other actors in the surroundings should facilitate the development, due to geographical proximity.	(Skellern, 2017)
	Developed technologies; the collaborations are aimed to implement technologies, not to work on innovation, or technological development. Present technologies will facilitate therefore.	General Idea		**Potential for R.E. generation;** the idea that R.E. generation is geographically possible, should facilitate the development, since the possibility is already known.	General Idea
				Network Intergration; tighter bonds in the network should lead to better collaboration, and faster development	(Newell, 2017) (Lutz, 2017)

Figure 4.7. – The list of facilitators as an input for the sorting exercise

4.2.3 The Barriers

The list of barriers in the sorting exercise is presented in figure 4.8. The barriers are the factors of influence that will hinder the collaboration. The presence of these factors will slow down the further development. A brief introduction into the barrier is presented based on the information found in the source. If no explanation is provided, no information was present.

The list of Barriers as an input for the Sorting Exercise

CC	Barrier	Source	CC	Barrier	Source
Communication	**Sharing of knowledge is difficult;** if trust, and shared vision are absent, actors don't share information, which hinders the development	Krijger (Skellern, 2017) (Negro, 2007) (Chow & Chan, 2008)	Collaboration	**Lack of involvement actors;** if some actors are not as involved as others, the development does not progress at the same pace, potentially hindering the development.	Krijger
	Lack of knowledge; unexperienced actors hinder the development	(Negro, 2012)		**Internal corporate culture;** if the companies are not willing to adopt new technology, or not willing to change, this hinders the development.	Krijger
	No coordinating actor present; see Property & facilitator	Krijger		**To weak interactions;** there is a collaboration, but no real ties between the actors, no real feel of the collaboration leading to a slower development.	(Negro, 2012)
	Withholding of information; causes not all information to be present in the network, potentially hindering the development	Krijger		**Lack of trust;** causes actors not to put all cards on the table, and be hesitant in their contribution. Actors do not know what to expect of others, this makes progress in the development difficult	Krijger (Skellern, 2017)
Political	**Hindering Regulations;** regulations block the further development leading to delays ,or long –term processes.	Krijger		**Stepwise Formal Process;** a stepwise formal process causes a very rigid collaboration, in which many time consuming formal requirements are present.	General Idea
	Legal Constraints; see barrier of hindering regulations	Krijger (Newell, 2017) (Polzin, 2017)		**Key actors leaving the project;** knowledge, commitment will leave the project, hindering the development	(Ruppert-Winkel, 2012)

	Lack of Hard Institutions; there are no regulations structuring the development, potentially causing uncertainty in the development.	(Negro, 2012) (Späth & Rohracher, 2010)		**Conflicting Interests;** if different actors do not share the same interests, these could become hindering factors.	(Skellern, 2017) (Newell, 2017) (Lutz, 2017)
	Lack of Soft Institutions; the legitimacy for actors to engage in the development is absent.	General Idea		**Too many actors involved;** the development consists of too many actors. The overview is lost, and no structure in the development.	General Idea
	LegaL Uncertainties; see lack of hard institutions.	(Newell, 2017)		**Uncertainty about the outcome;** causes actors to have doubts, and the withdraw from the development.	Krijger (Walker, 2017)
Economic	**Increasing costs of collaboration;** the costs of the development increases as the collaboration progresses, causing actors to invest more.	(Newell, 2017)	Technological	**Immature technologies;** cause the fact that the technology cannot be implemented directly	(Mankins, 1995) (Mankins, 2009)
	Dependency on subsidy/funding; the development is dependent on subsidy, the absence of subsidy thus hinders the development	(Lutz, 2017)		**External implementation problems;** the technology is present, but the environment and surroundings of the development cause implementation problems for the technology	(Mankins, 2009) (D'Agostino & Delaney, 2015)
	Absence of investment budget; all the developments start with an investment, the absence hinders the collaboration.	Krijger			
	Disagreement on allocation costs/benefits; hinders the development if not all actors agree.	Krijger			
	Disagreement on allocation of risk; risk should be spread proportionally.	Krijger			

Figure 4.8- The list of barriers that forms an input for the third part of the sorting exercise.

Chapter 5

Tata Steel Cases

In order to validate the lists that were presented in the previous chapter multiple experts were needed. Based on the criteria mentioned in Chapter 2, actors with experience in socio –technical systems were selected from cases of Tata Steel IJmuiden . Multiple cases of Tata Steel were studied, which resulted in three chosen cases. The cases are presented briefly, and the interview contacts that were obtained are introduced. Although there was a limited environment to choose experts from, and time constraints existed, a representative selection of experts was made to validate the lists of properties, facilitators, and barriers. The sorting exercises, and the methodology are explained in Appendix D.1 & D.2.

5.1 Background of the Cases used for the Expert Interviews

Tata Steel is subject to the changes that the energy transition entails, in terms of reducing energy usage, and CO2 emissions. The company is actively involved in this transition by efforts to reduce the CO2 emissions of their production processes, as the main focus of their contribution to the energy transition. Tata Steel is bounded by governmental regulations on energy and emission targets. As an example, Tata Steel is part of the Meerjarenafspraak Energy-efficiency ETS-ondernemingen. In this agreement a 1% energy reduction in production processes is strived for on yearly bases. It is among other things these incentives that make Tata Steel look for options on saving energy and reducing CO2 in the production processes. Besides the production processes, however, Tata Steel wants to contribute to the energy transition in all possible ways. Although the company has a clear priority in investing in steel production, since this is a core business, different renewable energy, and waste heat projects are pursued in collaboration with other actors. In striving for a more sustainable society, contributing to the renewable energy targets of the government for 2020 (and beyond), and improving the local environment.

The projects require collaboration with other companies, governmental authorities, research institutes, local interests groups, and action committees, due to multiple reasons. At first, since the expertise on renewable energy projects and district heating networks is missing in the company. Tata Steel produces steel, and wishes to play a part in the energy transition by engaging in these project. The expertise on how to conduct the project is, however, missing. As a second reason, the investment budget for the renewable energy projects is low, due to the focus on the core business of steel making. Other actors are actively pursued to engage in collaborations, to execute to projects. Finally, the projects have an impact on the environment, and the energy system not only on the TSIJ –site, but also outside of the gate.

Rules & Regulations, different interests, environmental laws, and policy on different scales, but also other companies, and actors, are all influencing the development of the projects, causing the need to collaborate. The cases are selected as examples of projects that are conducted in a network of actors that add to the socio –technical system.

It is these socio –technical projects that were aimed for when looking for experts to conduct the sorting exercise with. A total of three cases was selected in consultation with my thesis supervisor, based on the criteria presented in chapter 2. Two cases on developing renewable energy at the TSIJ -site, and one case on the development of a DH -network were selected. The three cases are presented briefly.

5.1.1 The development of Wind Park Ferrum

The first selected case is on the development of Wind Park Ferrum at the TSIJ -site. The IJmond region was indicated by the province of Noord-Holland as a potential location for the realisation of wind turbines, in the policy for 'Wind op Land' (N-H, 2018)**.** Already three wind turbines are present at the Reyndersweg, right outside of the TSIJ –site, and the number could be expanded. Tata Steel looked for options to place multiple wind turbines on site. Different scenarios for a new wind park were drafted. One scenario was finally approved by the licensing authority. In this scenario, 3 new wind turbines, with a capacity of 2MW, are placed in the extension of the currently existing 3 at the Reyndersweg (Wind Park Ferrum, 2018). Tata Steel looked for collaboration with different public, and private parties to execute the project on Wind Park Ferrum, since Tata Steel had no experience with building a wind park, and all the related procedures. From the experts that were part of the project a selection was made for the interview. The selection was approached for the semi –structured interviews and sorting exercises.

In the development of Wind Park Ferrum, multiple public and private actors were included in the network of actors. This network of actors tries to develop the wind park, and connect it to the Dutch electricity grid. The development was influenced by multiple provincial, and local decrees on wind parks, but also by long term licensing procedures, and safety rules and regulations. These factors made the Wind Park Ferrum case an example of a low level socio -technical system, and suitable to provide experts for the expert interviews. In appendix C.2 the development of Wind Park Ferrum is described in detail to present the socio –technical characteristics of the case, and the current status of development. The following experts were selected based on the case of the development of Wind Park Ferrum:

Number	Role	Tata Steel / External
1	Project Manager Energy Efficiency	Tata Steel
3	Project Manager Wind Project	Tata Steel
5	PR manager Wind Project	Tata Steel
7	Representative Common Interests (Wind Park)	External
8	Project Manager Wind Park & Solar Panel Project	Tata Steel
10	Licensing Authority Wind Park	External

5.1.2 Developing Solar Power on site at TSIJ

The following case was on the development of solar power at the TSIJ -site. In 2012 the first solar panels at the TSIJ -site were constructed on top of the Dudok Huis[4]. These solar panels, a total of 500, have a capacity of 0.1MW. This was only a very small part of the total potential for solar energy on top of the roofs of production facilities. In order to utilize the potential, contribute to the energy transition, and improve the green image of Tata Steel, the motivation was present to start a project on placing solar panels on top of production facility roofs at the TSIJ –site. In collaboration with other partners an initial SDE+[5] subsidy for a total of 3 MW of solar panels was applied for. An additional subsidy for 19 MW of solar panels was requested, resulting in a total of 22MW of solar energy subsidy. In the development of Solar Power at TSIJ, multiple actors were present representing different interests, who had to work together to add to the technical system by installing solar panels. Different technical problems, or unexpected events occur to which the network of actors had to react. The SDE+ subsidy, an institution, created the incentive to work together and thereby influenced the network of actors. These factors made the case of Solar Power at TSIJ an example of a low level socio -technical system. Different experts active in the case were approached. In Appendix C.3 the case of solar power development at the TSIJ –site is presented in detail, showing the socio –technical characteristics of the case. Different experts active in the development of the project were approached for an interview and the sorting exercise. The following experts were selected based on the case:

Number	Role	Tata Steel / External
4	Actor Solar Panel Project	Tata Steel
8	Project Manager Wind Park & Solar Panel Project	Tata Steel
11	Project Manager Solar Panel Project	Tata Steel
13	Energy Department	Tata Steel
15	Actor Solar Panel Project	Tata Steel

[4] Dudok Huis is the main building at the entrance of the TSIJ –site.
[5] SDE+ subsidy is explained in Appendix H

5.1.3 Creating a DH –network in the IJmond Region

The final presented case covers the creation of a DH -network in the IJmond region. In process of steel making, the generation of waste heat is inevitable. The re –use of this heat in internal company processes has the priority for Tata Steel, but the growing number of projects, and the increased interest in district heating networks shows a potential for external. This external use of heat produced by Tata Steel is not present as of yet, but Tata Steel is active in a collaboration with multiple public and private parties to develop a district heating network for the IJmond region. The heat generated by Tata Steel could be used to heat buildings in the region. The trigger to look for the possibilities of a DH –network was given by Gerard Jagers (Tata Steel), and a local councilman supporting the development of a DH –network in the IJmond region. Besides this, a good score (B) in terms of sustainability for heat produced in Tata Steel processes, caused an incentive to look for the options on district heating development(Kalkman & Menkveld, 2017). In the case of developing a district heating network in the IJmond region, multiple public and private actors were active to develop a completely new technical system in the form of a district heating network. The supply and demand side of the heat had to be combined, and the absence of clear institutions influenced the development of the network sometime positively, sometime negatively. The development of the district heating network is thus a clear example of a socio -technical system. In Appendix C.4 the case on the development of a DH –network in the IJmond Region is presented in more detail to show the socio -technical characteristics of the case. The following experts were selected:

Number	Role	Tata Steel/ External
1	Project Manager Energy Efficiency	Tata Steel
2	Energy Consultant	Tata Steel
6	DH – network developer	External
9	DH – network consultant	External
12	Representative DH – network (Public)	External
14	Representative DH – network Local Government (Public)	External

Chapter 6

Results, and Analysis

In the previous chapter, the cases of Tata Steel IJmuiden were briefly introduced. The cases provided the experts that filled in the sorting exercises. The results of these sorting exercises are presented and analysed in this chapter to draft the new NRL -scale. Before the results are an input for the draft of a new methodology, different steps of analysis are necessary to change the outcomes of the sorting exercise in combination with the expert opinions into scale to indicate readiness. The results are analysed based on the four- step method that was presented in Chapter 2.

The results of the sorting exercise are presented and selected in paragraph 6.1, as the first step of the analysis. The results are interpreted in paragraph 6.2 in the second step. The interpretation forms the input for the draft of a method to assess the readiness of the development in paragraph 6.3. Finally, in paragraph 6.4 the new methodology is created based on the insights of the previous steps of analysis.

6.1 Presenting the Results of the Sorting Exercise

During the sorting exercises of the interviews, the network properties, facilitators, and barriers came forward, presented three lists. In this paragraph, the numerical results of the sorting exercises are presented. Before the numerical results of the sorting exercises are presented, a brief remark is made about the fact that the outcomes of the sorting exercise of the properties, is different from the outcome of the sorting exercise of the facilitators & barriers, due to a different structure in the sorting exercise. [6]

6.1.1 Properties Sorting Exercise

A total of 14 respondents chose from a list of 15 properties. A selection of the most chosen properties is made to form an input for the NRL draft. In this sub –paragraph the chosen properties, the properties that were out of scope, and the properties that were not chosen by the respondents are presented.

[6] The difference between the sorting exercise of the Properties, and the sorting exercises of the Facilitators & Barriers is explained in Appendix D.1 & D.2

Chosen Properties

As a first property 4 out of 14 respondents mentioned **formal contracts**, with an average sorting value of 0.7[7]. Besides the importance of formal contracts, 4 of 14 respondents explicitly mentioned the importance of a **DOI/LOI** in the earlier phases of the development, as a first formalization. Therefore, the LOI/DOI is included in the draft of the NRL. The presence of a **central coordinating actor** is mentioned by 7 out 14 respondents, with an average sorting of 1.3. 10 out of 14 respondents mentioned **shared vision** as an important property, with an average sorting value of 2.6. **Trust** among the actors was mentioned by 13 out of 14 respondents, with an average sorting value of 3.8. This means trust was mentioned by the most respondents, and received the highest average sorting value of all properties. Besides trust, the **transparency** of actors during the collaboration was mentioned by 8 out of 14 respondents, with an average sorting value of 1.6. As a final property, the **reliability** of actors was mentioned by 7 out of 14 respondents, with an average sorting value of 1.5.

Out of Scope

Three properties are considered out of scope in this research. The properties were mentioned during the sorting exercise, but are not taken into account, due to divergent reasons. The properties are; like-minded actors, informal relationships, and multi -level relationships. **Like minded actors** was mentioned by 3 out of 14 respondents. This is; however, closely related to the property of **shared vision.** Therefore, the **like -minded actors** are classified under the **shared vision**, and not included as a separate property. **Informal relations** between actors were mentioned by 3 out of 14 respondents, but are not taken into account. These are personal relations between the actors, and are helping in the first stage of the collaboration, but are not enough mentioned, and motivated to use in the draft of the NRL. Although the property of **multi -level collaboration** was mentioned by 5 out of 14 respondents, the property is not taken into account. This is because of the different perspective of the respondents on the meaning of multi -level collaboration when filling in the sorting exercise. Some respondents referred to the multiple -levels of management needed in a collaboration internally, while others referred to the necessity of collaboration with different levels of government (national, regional, local). This resulted in a dispersed way of filling in the sorting exercise, and an answers with various perspective. Therefore, the multi –level collaboration is placed out of scope.

Not -chosen properties

Three properties were not mentioned by the respondents in the sorting exercise as properties of collaboration; **actor heterogeneity, institutional frameworks guiding the collaboration, and the absence of competition.** As a result these properties are not included in the draft of the NRL.

Concluding Remarks

Seven properties mentioned during the interviews, were selected based on the outcomes of the sorting exercise. The seven properties are; formal contracts, LOI/DOI, central coordinating actor, shared vision, trust, transparency, and reliability.

[7] The Sorting Exercises are explained in Appendix D.2. The average sorting value mentioned here is the average value the property received over all 14 respondents, so also the respondents that did not pick the property. The maximum average sorting value was 5. This was when all the respondents picked the property, and gave tt value 5.

6.1.2 Facilitators Sorting Exercise

The same 14 respondents filled in the sorting exercise regarding the facilitators of a socio –technical system. The sorting exercise existed of 6 coding classes, containing a total of 24 facilitators to choose from. The numerical outcomes for the different coding classes are presented in combination with the most mentioned facilitators within each coding class. Only the chosen facilitators are mentioned, due to the large amount of facilitators that were present in the sorting exercise. This provides the structure of presenting a coding class, followed by the most mentioned facilitators within that coding class.

Collaboration

The coding class of **collaboration** received an average sorting value of 4.1, thereby the highest sorting value of all facilitator' coding classes. Within collaboration, the **willingness to share resources** was mentioned by 12 out of 14 respondents as a facilitator. Besides this, the presence of a **central coordinating actor** was mentioned by 7 out of 14 respondents. The central coordinating actors was already named as a property of collaboration, and will therefore be presented as a property in the remainder of this research. The **presence of key actors** supporting the process was also by 7 out of 14 respondents. As a final facilitator, the presence of **well established relationships present at the beginning of the collaboration** was mentioned by 6 out of 14 respondents.

Communication

Communication as a coding class was scored with an average sorting value of 2.9. As specific facilitators; the **alignment of interests** was mentioned by 11 out of 14 respondents, followed by **set targets and goals** in the development by 4 out of 14 respondents. Facilitators regarding the method and frequency of communication were presented in the sorting exercise, these were, however, not chosen by the respondents. The facilitators of communication are thus more focused on the content, than on the method of communication.

Political

The coding class of **political** factors as a facilitator was scored with an average sorting value of 2.3, showing a low importance among respondents. The **support by decision** makers was the only facilitator selected, since this was mentioned by 10 out of 14 respondents as a facilitator.

Economic

The facilitating impact of **economic factors** on the collaboration received an average sorting value of 3.1, which is the highest value besides the value of collaboration. **Financial gains** was mentioned by 5 out of 14 respondents as a facilitator. The other two facilitators that were present in the coding class of economy; availability of subsidy, and possibility to find investors, were only mentioned two (availability of subsidy), and three (possibility to find investors) times respectively, and are not included.

Not -chosen coding classes

Technological, and geography were the final two coding classes present in the sorting exercise. Technological scored an average sorting value of 1.5, and geography scored an average sorting value of 0.9. This shows the low facilitating impact of technological, and geographical factors in collaboration. As a reason for the low value of **technological** facilitators, a clear explanation was presented by the respondents. All projects concerned were focused on the implementation of existing technologies, rather than the development of technologies, and innovation. According to five respondents the technological solutions were nearly always present, and technological factors were not specifically facilitating the projects. Therefore, the technology is not considered a facilitator in the NRL draft.

The **geography** received an average sorting value of 0.9, and was only important for the local actors (local government, interests groups). The fact that different actors were in **geographic proximity** was not considered an important facilitator for collaboration, which can be concluded from the 1 out of 14 respondents that filled in proximity of actors as a facilitator. The **geography** of the network is not included in the NRL draft based on the low average sorting value, and only 1 out of 14 respondents filling in the geography as a facilitator of collaboration.

Concluding Remarks

Within the four coding classes of facilitators, a total of 8 specific facilitators was selected, based on the outcomes of the sorting exercise; willingness to share knowledge/resource, central coordinating actor, presence of key actors, well established relationships, alignment of interests, set targets & goals, support by decision makers, financial gain.

6.1.3 Barriers Sorting Exercise

The sorting exercise on the barriers consisted of 5 coding classes and a total of 26 barriers, which was filled in by 14 respondents. The numerical outcome of the coding classes is presented, and the most mentioned barriers in each coding class are explained.

Collaboration

The coding class of **collaboration** was scored with an average sorting value of 4.1, thereby the barriers regarding collaboration received the highest average sorting value. Within the coding class of collaboration, **conflicting interests** of actors was mentioned by 10 out of 14 respondents as a barrier. The **lack of trust** among actors was mentioned by 8 out of 14 respondents, however, the importance of trust is already mentioned as property in paragraph 5.1.1. The **lack of trust** will therefore not be discussed as a barrier. Finally, the **uncertainty about the outcome** was mentioned by 5 out of 14 respondents.

Communication

Communication received an average sorting value of 2.6. In the coding class of communication, the barrier; **knowledge sharing is difficult** was mentioned by 5 out of 14 respondents. In relation to the difficulty of sharing information, the **withholding of information** was mentioned by 3 out of 14 respondent as a barrier.

Political

The coding class of **political** factors as a barrier of collaboration received an average sorting value of 3. Within the coding class, the barrier of **legal constraints** was mentioned by 6 out of 14 respondents. The presence of **legal uncertainties** was mentioned by 4 out of 14 respondents as a barrier of collaboration.

Economic

The coding class of **economic** factors was scored with an average scoring value of 3.7. The barrier that was mentioned most, was the **disagreement on the allocation of costs and benefits,** by 8 out of 14 respondents. The barrier was followed by the **sharing of risks,** mentioned by 4 out of 14 respondents.

Technological

Technological factors functioning as a barrier was scored with an average sorting value of 1.4. No specific technological barrier was mentioned by the respondents, since the technology was expected to be present, as was the case in the facilitators sorting exercise.

Remarks that were made were: 'In the field of technology we will always find a solution'(Interview 8) , or 'Technology is not a problem, since this is present'(Interview 2). For the implementation of the technology; however, an important factor is discussed, which was not included in the sorting exercise. This barrier of **non- implement ability of technology in the environment**. Not being able to implement a technology in the environment could be a barrier if a new technology has to be implemented in a process, in its surroundings, or next to other projects that are conducted. This This factor is considered in the draft of the NRL, because of the mentioning by respondents during the sorting exercise. This differs from the normal structure, but makes sure the technological barrier is included in the NRL draft.

Concluding Remarks

The five coding classes were presented, and briefly discussed. The collaboration barriers received an average sorting value of 4.1, thereby the most important barrier. The technological barriers received an average sorting value of 2, thereby the least important barrier. A total of 10 barriers were explicitly mentioned during the sorting exercise; conflicting interests, lack of trust, uncertainty about the outcome, knowledge sharing is difficult, withholding of information, legal constraints, legal uncertainties, disagreement on the allocation of costs and benefits, disagreement on the sharing of risks, non –implement ability of the technology.

6.1.4 Selected Properties, Facilitators, and Barriers

In the paragraphs 6.1.1 till 6.1.3, the properties, facilitators, and barriers that influence the socio – technical system, were selected based on the first analysis step of the results. Figure 6.1, presents the factors that were selected. These factors are input of the second step of result analysis.

Properties		Facilitators		Barriers	
	Formal contracts	**Collaboration**	Willingness to share resources/knowledge	**Collaboration**	Conflicting interests
	LOI/DOI		Central Coordinating Actor		Lack of trust
	Central coordinating actor		Presence of Key Actors		Uncertainty about the outcome
	Shared Vision		Well established relationships		
	Trust	**Communication**	Alignment of Interests	**Communication**	Knowledge sharing difficult
	Reliability		Set Targets & Goals		Withholding of information
	Transparency	**Political**	Support by Decision Makers	**Political**	Legal constraints
					Legal uncertainties
		Economic	Financial Gain	**Economic**	Disagreement on allocation of costs and benefits
					Disagreement on sharing of risks
				Technology	Non -Implement ability of the technology

*Figure 6.1 – Table of the chosen properties, facilitators and barriers of collaboration based on the outcomes of the sorting exercises. The different coding classes used in the Facilitators & Barriers sorting exercise are presented in **bold.***

6.2 Interpreting the Sorting Exercise Results

The numerical outcomes of the sorting exercises are further analyzed to serve as an input for the draft of the NRL, since they represent only a numerical value without an explanation. In this paragraph, one property, one facilitator, and one barriers from figure 6.1 are presented as an example to show the method used for interpretation. The remainder of the properties, facilitators, and barriers is presented in **Appendix E.** Each factor is connected to theory (if possible), and discussed based on the expert opinions. The connection to the literature is made to explain the meaning of the factor more elaborately. The expert opinions are presented to show the motivation to include the factor in the NRL –scale. After presenting the factor as connected to theory, and to remarks made by the experts, the factor is connected to a level of development, based on a motivation in the literature, and interviews.

Besides including the PFB's selected from the sorting exercise, specific remarks made by respondents are included, to provide a broader scope than just the preselected factors. An example of a remark is; the need for good **partner selection** at the beginning of the development. This was mentioned by 3 respondents, but was not preselected in the sorting exercise. Based on the remarks during the interviews, it is selected as a facilitator. The selection of the final remarks is based on the number of times they are mentioned in the interviews, and the relevance of the factor for the research, assessed by the researcher.

In some cases the property, facilitator, or barrier is only interpreted based on the expert opinions expressed during the interviews, but not connected to theory. This is when the factor is presented by a general description, such as; support by decision makers, well established relationships present from the beginning, or financial gain. These factors are not connected to literature due to this general representation, and only interview specific remarks are presented.

As a final result of the second step of result analysis, **Table 1** is drafted. This table provides a first overview of the properties, facilitators, and barriers mentioned during the analysis, assigned to a level of development.

6.2.1 Properties

The properties of collaboration are presented based on the properties that came forward during the sorting exercise. In the sorting exercise, no coding classes were used, therefore the individual properties are presented.

Formal Contracts

Theory
4 out of 12 respondents mentioned **formal contracts** in the sorting exercise. Contracts are the formalization of trust between actors, leading to risk -reduction in collaboration, allowing for long lasting collaboration based on trust. The contracts achieve this by providing continuity, and structure in collaboration (Vlaar, 2006). Besides this function, they provide clarity in situations of conflict, and complications (Poppo & Zenger, 2002). Two perspectives on the connection between formal contracts and trust are present in literature.

A first perspective on the formal contracts is the complementarity of contracts and trust (Blomqvist, Hurmelinna, & Seppänen, 2005; Czernek, Czakon, & Marszałek, 2017). In this sense, the trust between actors leads to a contract, and the contract is a formalization of trust. The one leads to the other. Another view on contracts is the contract as a substitute of trust. Contracts are only drafted when there is no trust in the collaboration. The presence of one reduces the necessity of the other (Bachmann & Zaheer, 2006; Czernek et al., 2017). Sometimes even to the extent that the formal contracts can hamper the development of trust in the related project (Bernheim & Winstion, 1998).This shows the ambiguous interpretation of the role of the contract in theory.

Interviews

The former understanding of complementarity between formal contracts and trust, became apparent during the interviews. One interviewee mentioned that contracts are necessary to formalize the trust between actors, and to build support within the different organizations (Interview 13). Besides this, the formal contracts are needed to provide clarity in long term collaborations, which are common in energy related projects. For instance due to the basis of a 15 year SDE+ program, the collaborations are long –term, and contracts need to structure these, as was stated by Interview 2. This structuring function of a contract was expressed more in the interviews. Without contracts, projects are not going anywhere. The contracts need to structure the process and specify the **business case, allocation of risks, and tasks,** as was mentioned by interviewee 2. Contracts are needed to make the standpoints of the actors clear, and provide structuring elements such as division of costs & risks, and tasks (Interview 6).

In the previous section, contracts are described as a formalization of trust, or a final structure for the collaboration. In the process before the contracting, the **LOI/DOI** is an important first formalization of trust, according to remarks made by five respondents. A first division of what will be done in a collaboration, the tasks of the different actors, a working plan, and costs & risks is made in the LOI. NDA's and agreements on how to part ways when the collaboration fails could be included, as was stated by Interview 6 and 15. The LOI, however, is not binding, and only works as a step in the formalization of trust, and commitment (Interview 8, 11 & 14). The intent of different actors, and agreements on the **distribution of tasks,** becomes clear in the LOI, according to interview 15. This distribution of tasks is important to prevent 'double work', and divide the workload from the beginning (Interview 3). In between the **LOI/DOI,** and the signing of the formal contract, a second LOI, or Collaboration Agreement can be necessary, based on new developments in between the two documents (Interview 2 & 6). The decision to draft a second LOI, or CA is project specific, and will be included as a finding in the NRL.

Given the above description of formal contracts in both theory, and interviews, the contract functions as a formalization of trust, and provides necessary structure. The LOI is a first step in this process, not binding the actors, but displaying intent and a first formalization of trust. The LOI, therefore, is drafted first in NRL 3. The LOI is expected to be signed in NRL 4, since first negotiations have taken place and trust among the actors had developed. The contract is expected to follow the LOI, and is drafted in NRL 5. In NRL 6, the contract is expected to be signed, based on a final formalization of trust. From this point on the actual creation of technological output in the socio –technical system could start.

6.2.2 Facilitators

The facilitators are discussed based on the six coding classes that were used during the sorting exercise, and the most important facilitators that came forward in each coding class. The coding classes are mentioned first, presented in blue (Collaboration). The respective facilitator follows (Willingness to share resources and knowledge). About the coding classes, no further information is provided, whereas the facilitators are explained in detail. The same structure of presenting the facilitator connected to theory, and to the outcomes of the interviews is used.

Collaboration

Willingness to share resources and knowledge

Theory

The **willingness to share resources and knowledge** in a collaboration is partly dependent on the amount of **trust** experienced between different actors(Napahiet & Ghosal, 2018). When experiencing trust, knowledge sharing becomes easier, since the suspicion of opportunistic behaviour is absent(Ring & van de Ven, 1992). Sharing knowledge is further influenced by individual motivation to share knowledge, the value of knowledge shared, reciprocity (do we get something back for sharing knowledge), and the reward(what do we get back) that is perceived when sharing knowledge (Ipe, 2003; Ramim & Lichvar, 2013). This shows that sharing knowledge is both influenced by trust, and the perceived profit of sharing knowledge. When the notion is created that sharing of knowledge increases the value of knowledge in a network, since it is shared among others, the sharing contributes to the final goals and shared interests of the actors (Ramim & Lichvar, 2013).

Interviews

The **willingness to share resources and knowledge** was mentioned by 12 out of 14 respondents as a facilitator.This facilitator is connected to trust, shared vision and transparency. The three properties cause the willingness to share resources and knowledge to grow, as was stated by interview 12. Sharing knowledge creates the situation in which all the knowledge is present in the network, and multiple actors could benefit from this. It creates transparency, and shows that different actors are not 'keeping their cards closed', as was stated by interview 2 & 12. A way to stimulate sharing of knowledge, is by **becoming familiar with the background of the actors**, and their supporters (Interview 12). This creates a working environment in which the actors do not only understand what is driving, or sometimes hindering the collaboration, but also how actors are limited in their possibilities.

Another way to facilitate the willingness to share resources, is by **creating the image of a 'must have' technology, or project,** instead of a 'nice to have' one (Interview 9 & 15). The necessity of sharing knowledge, and resources becomes clearer based on this image. An example is the development of the DH- network. If the actors are aware of each other's backgrounds, and share the image of a 'must have' technology, an incentive could be created to share knowledge (Interview 9 &12).

To summarize, the sharing of knowledge, and resources becomes easier with trust, knowledge of the background of actors, and the image of a 'must have' project. Two facilitators are therefore included in the NRL; the **knowledge of actors' background**, and the **image of a 'must have' project.** In NRL 2, the knowledge of the actors' background needs to develop, based on actor meetings taking place during this phase. Besides the background knowledge, a 'must have' image is a potential facilitator in NRL 2 that should encourage different actors to continue the collaboration. The actual willingness to share knowledge and resources is facilitator in NRL 3, since the actors are together in the network, have to express their intent, and make agreements on the further steps of the collaboration.

6.2.3 Barriers

The barriers are presented by the five coding classes that were used during the sorting exercise. For each coding class, the most important barriers coming forward during the sorting exercises are discussed. The coding classes are mentioned first, and the respective barriers explained after this. About the coding classes, no further information is provided, whereas the facilitators are explained in detail. The same structure of presenting the barrier connected to theory, and to the outcomes of the interviews is used.

Collaboration

Conflicting Interests

Theory
The **conflicting interests** exist in a collaboration, since the conflict in interests emerge from nested perspectives about goals of collaboration (Finch, Zhang, & Geiger, 2013). Different perspective on the outcome of the collaboration lead to a conflict in interests. The different actors in the network typically require adaptation, through modifying beliefs and behaviour, to overcome a conflicting interest(Finch et al., 2013). Conflicting interests is something typically emerging in the beginning stages of the collaboration, since different 'new' actors are discovering perspectives, and goals within the network (Roloff, 2008). By aligning the interests of the different actors, the problem of conflicting interests can be resolved. Aligning could be done by creating a common final goal in the collaboration. This approach looks at an active approach of solving conflicting interest. Another idea, is that during the process of collaboration, the organizational fit becomes better, and the partners' missions, values, and strategies will be more aligned, as a result of working together successfully, and the growth of deeper trust (J.E. Austin & Seitanidi, 2012).

Interviews
Conflicting interests was mentioned by 10 out of 14 respondents as a barrier, and is connected to the positive facilitator of **alignment of interests.** The barrier arises in a collaboration when some actor see the projects in terms of a business case, while other parties have a sustainable vision, or want to serve the general interest (Interview 7). Different actors have different views, or images of the process, and the outcome of the collaboration. Aligning this is important to keep everybody on board during the project (Interview 7, 8, 9& 14).

It is not necessarily the **conflicting interests** that are hindering the collaboration, but it could also be just **different interests** of the actors, as was mentioned in a nuancing remark by interview 8. As an example, the different actors in the Wind Park Ferrum project understand the value of the wind park in terms of the financial value, sustainable value, and contribution to society. All actors, however, have their own interest in the project. The developer wants to make profit, and create a green image, Tata Steel wants to contribute to society, and the local residents want to protect their interests, and potentially participate. The interests of the actors are different, but not necessarily conflicting.

The different interests could arise because actors **talk different languages**, and share different images regarding the project (Interview 12). The motivation expressed by actors to serve their own interests is not always understood by the other actors. For example, the housing corporations felt part of a business case in the development of the DH -network, instead of being part of a serious project in which they could express their interests and work together (Interview 13).

Another reason for conflicting interests is the **complexity of the projects**. In the case of the DH –network, this comes not only forward due to the large number of actors involved, but also because the streets need to be opened up, technologies need to be implemented, and investment decisions need to be aligned (Interview 12). This causes many different interests to be present in a single project, and conflicts to arise.

One way to resolve the barrier of conflicting in interests is by **aligning interests** of the actors (discussed in Appendix E.1), and creating the **same image** in all actors. This could be done by installing a central coordinating actor (Interview 8, 12 & 14), who tries to solve conflicts in interests as being the central actor. Sometimes, however, an overarching organization like the government should pursue this role (Interview 12).

As an example the development of the DH -infrastructure is presented, since the overarching province could pursue the alignment of interests. The province has an overlooking role in the development of the DH -infrastructure in the IJmond region. In the IJmond region, a smaller consortium is working on the development of the DH –network, facilitated by the OD IJmond. In its role, the province could signal tension and conflict within the smaller collaboration in IJmond. As an outside actor the province could facilitate the alignment of interests by making sure the actors within the consortium understand each other, and share the same final image (Interview 12). The interests are thereby aligned by an outside actor, capable of looking at the network from an outside scope.

As can be concluded from the above, the **conflicting interests** in a collaboration arise from different goals, and perspectives in a collaboration. The conflicting interests become clear during the first meetings in which the actors are trying to share a vision on the project. The conflicting interests could be caused by actors talking a different language, and incomprehension among actors on the final vision. When this is the case, the conflicting interests cause a barrier in NRL 2. The conflicting interests are the opposite of aligning the interests (which is a facilitator of collaboration).

The conflicting interests will, therefore, occur in NRL 2, and will need to be solved by aligning the interests in NRL 4, since the interests need to be aligned before further collaboration takes place, and the first formalizations in the collaboration are introduced. The complexity of project, leading to conflicting interests will only become present when the collaboration has reached an advanced stage, due to the insights into the feasibility of the project that have to be obtained first. The complexity could form a barrier in NRL 5, when the studies on the feasibility have been done.

6.2.4 Concluding Remarks Interpretation

In the previous three paragraphs examples are given of the interpretation of a property, facilitator, and barrier, based on literature and interview results. Based on the interpretation of the results in this paragraph, and in the appendix, two important preliminary conclusions can be drawn. These are presented, because they provide insights which are used in the further analysis of the results. At first, the properties of shared vision, trust, and transparency, are seen as the pre –conditions of collaboration, based on the remarks by respondents. This means that these three factors have to be present in the collaboration, before the collaboration continues. As a second, important remark, the factors of influence could be divided into process factors, and product factors. The process factors are the soft factors of influence in a collaboration, like the trust, shared vision, transparency, but also commitment, and a bigger picture of the network. The product factors are the physical products of the collaboration, structuring, and formalizing the network, such as; LOI, contracts, and a central coordinating actors. The division into product, and process factors is used in the following steps of analysis, and is therefore mentioned in these concluding remarks.

6.2.5 Table 1: the PFB Table

In Table 1, the properties, facilitators, and barriers, discussed in this paragraph are presented and connected to a level of development. Table 1 serves as an overview, and a summary of the first step of result analysis. On the x – axis the levels of development of the NRL –scale are presented. On the y-axis the properties, facilitators, and barriers that were determined based on the interpretation of the numerical results are shown. By using Table 1, the user obtains an insight into the different factors of influence, and the actions that could facilitate, and hinder the further development of the network of actors. To determine the level of development, Table 1 is not suitable, since it is only used to provide an overview of the factors.

In Table 1 seven levels of development are presented (NRL 1 – NRL 7). The levels are divided over four phases of development. NRL 1-2 represent the exploration phase of the network, since the actors of network are looking for options. The NRL 3-4 is the concretization phase, since the actors are together in the network, and are for instance working towards a division of tasks, a shared vision of the goal, and a division of risks. More concrete plans of collaboration are formed. NRL 5-6 is the formalization phase of development, since the actors are working towards a contract, but are also researching the economic and technical feasibility of the project. The final phase, NRL 7, is the execution phase in which the agreements are executed, and the output of the network is presented. The properties, facilitators, and barriers are connected to the level of development in which they are expected to occur, motivated by the literature, and the remarks by respondents

The table only provides a clear overview of the most important PFBs in a network of actors. The properties, and facilitators are expected to be cumulative, which means that once a property, or facilitator is present in a NRL, the specific property, or facilitator is expected to remain present. The transparency once shown by the actors should remain present during the remainder of the collaboration. The dynamic character of network development, further explained in the fourth step result analysis (paragraph 6.4.), changes this idea of the cumulative properties, and facilitators. The barriers are expected to be present in the specific level of development they are placed in, because the barriers need to be resolved before the network could develop towards a higher level.

Table 1	Exploration		Concretization		Formalization		Execution
NRL	1 Triggers of Collaboration	2 Potential Network for STS	3 First formalization of trust	4 Risks, Cost & Benefits allocated	5 Feasibility of the Project is Clear	6 Towards the Contract	7 Contracts Signed & Start Construction
Properties	Historic Trust	Trust (grows) Shared Vision (grows) Transparency (grows) Historical Reliability	LOI/NDA (draft) Distribution of Tasks Authorization (for LOI) Assigning a CCA	LOI (signed) Performance Reliability	Contract (draft) Authorization (for contract)	Signed Contract	
Facilitators	Well -established relations Triggers	Good partner selection Involving All Actors Create 'Must have' image Familiar with background other actors Shared Final Image Among Actors	Commitment by key actors / management Willingness to share resources Change of mind –set Financial Gain becomes clear Support by decision makers	Positive Business Case Fair Sharing of Risks Targets & Goals of the project set Showing Commitment Aligned Interests	Implementable in the environment Gain of the Project clear Positive Business Case	Permits Financial Gains for all actors clear	Stability
Barriers	Bad Relations	Opportunistic Behaviour Talk different language Conflicting Interests Incomprehension among actors	Hidden Agendas Withholding of Information	Legal Constraints	Absence of Clear Benefits Regulatory Uncertainty Disagreement on allocation of costs & benefits Long -term procedures Internal Corporate Culture Hindering Collaboration Key actors leaving the process	Complexity of the Project (Technological) Non-implementable in environment Absence of information	Unpredicted Set-backs

6.3 Drafting the NRL Sufficient Condition & Indicators method

In the previous step of analysis, the different properties, facilitators, and barriers that influence the network of actors over time are discussed. The factors are connected to theory and the outcomes of interviews to motivate their inclusion. This lead to the draft of Table 1. Table 1 provides an overview of the factors present in a level of development, but does not provide the possibility of assessing the readiness of the network based on a level of development. In the next analysis step, therefore, the PFB's are translated into Sufficient Conditions & Indicators of the NRL. The translation is based on changing the PFB's into indicators of a level of development, and the creation of a sufficient condition for each level of development. No description of how each PFB is translated into an indicator of the level of development is presented, however, a description of what indicators are present in which level of development is provided. The description, presented in the next paragraph, presents the indicators in **bold,** and describes what actions need to take place in each level of development. Based on these descriptions, the Sufficient Conditions of the different levels of development are drafted. Finally, the method to indicate the readiness of the network of actors based on Sufficient Conditions & Indicators is presented in **Table 2: Sufficient Conditions & Indicators method.**

6.3.1 Description of the Sufficient Conditions & Indicators method

The description of the levels of the NRL is presented from NRL 1 to NRL 7. The reader could look for further motivation, and explanation of the PFB's in Appendix E of this research.

NRL 1

In NRL 1, an incentive for collaboration needs to be present, which could be originating from a **governmental request,** or **demand,** the potential of **financial gain**, the **necessity to work together**, **PR potential**, or **sustainability drive**. The need to collaborate is clear for the actors, in combination with an idea of the potential of working together in a project. **Historical trust** between actors can be present already, based on historical success in a collaboration with the same actors. In appendix G an overview of the incentives to engage in a network of actors is given.

NRL 2

The incentive to engage in the collaboration has been processed in NRL 2, and results in the **actor selection** of the network. Specific actor criteria are drafted by the initiator to structure this selection. Besides this, all the actors potentially involved should be included in the network; the **actor involvement.** If earlier projects with the same actors have taken place, there is **historical reliability** present among actors. Actor meetings need to take place in NRL 2, which should lead to a project plan, and the growth of the three pre -conditions of collaboration; **shared vision, trust, transparency.** The growth of the pre -conditions has led to the discussion of how to develop a system of information exchange, in terms of for instance a **NDA**, or free sharing of knowledge. The first discussions on a **LOI** take place between the actors.

NRL 3

Appointing a **central coordinating actor** to the project is an indicator for NRL 3. This CCA could be an internal actor, or an external unbiased actor, moving the project towards a common goal, and connecting the actors. All potential actors are present in the network at this point. Besides this, time and money were made available to make the **financial, technological, environmental** outlines of the project clear. These steps could not have been taken without **the willingness to share knowledge, and resources** among actors. The willingness is therefore expected to be present. Further, the expectations about the goal of the collaboration are aligned in the network, causing **trust, transparency, shared vision** to be present in the network, and an idea of the **collaborative interest** in the network. This has led to the draft of the LOI, as a first formalization of trust, and a first **allocation of tasks that actors** have to perform in the network. The **management/key actors** are informed, but also **committed** to execute the project. The commitment of the management/key actors means that the authority to sign a LOI is present in the network.

NRL 4

In the NRL 4, a signed **LOI** is needed as a first formalization of trust, and commitment by the actors, and management. The LOI, however, is not a binding agreement, and actors cannot be held to their commitment. If a 2nd LOI, or other collaboration agreement is needed, the development is expected to stay in NRL 4 until the documents are present. The **Risks, Costs & Benefits** need to be researched in NRL 4, and allocated to the actors. This means that the technological, and economical feasibility of the project are researched, and the required capital for the investment is present in the network. The interests in the network might be different, but the **collaborative interest**, and **the bigger picture** of working together in the network are present at this point. This gives leverage to the LOI signed in NRL 4. The impact of the **institutions** on the network needs to be known. Knowledge on the **legal constraints, uncertainties**, **or support by decision makers** is present in the network. The support by decision makers should be known on national, regional, and local scale. The **permits** needed for the development of the project are requested at the authorized governmental authority.

NRL 5

All knowledge on the project finances, technology, political influence, is present in the network, since the **feasibility** of the project needs be clear in NRL 5. This means that a positive business case, or the gain of the project is clear. Besides the feasibility, **the implement ability** in the environment needs to be clear in NRL 5. This means that the knowledge is present on how the project relates to the technological and company environment, and the surroundings in which it is implemented. The **contract** as a final formalization and the start of the real execution is drafted by the juridical departments of the actors, based on the **divided tasks**, **feasibility, the determined risks, costs & benefits** of the project. **Authorization** to sign the contract is present in the network, since the management/key actors are present.

NRL 6

A **signed contract** is present in NRL 6, and serves as the final formalization of the collaboration. All internal (company), and external (network) actors, that are needed, have signed the contract. All **permits, and the subsidies** for the development of the project are in, the finances for the project are present, and the subsidies that were applied for during the project are valid. All **legal uncertainties** hindering the development have been tackled.

NRL 7

In NRL 7, the network starts **constructing** the outcome of the collaboration. At the end, the formal delivery of the project takes place. Only **unexpected events** could influence the constructing.

6.3.2 Table 2: the Sufficient Conditions & Indicators method

In the previous sub -paragraph the different NRL levels are described based on the actions taking place, supplemented with the indicators for each level of development. The time scope of the description is from the incentive to engage in a network of actors to the signing of the final contract, leading to the possible start of construction. Based on the descriptions, Table 2 is drafted. The table present the Sufficient Conditions & Indicators method. On the x-axis the levels of development of the NRL –scale are presented. On the y –axis the Sufficient Conditions are presented, supplemented with the Indicators (divided over Product & Process –indicators).Table 2 could be used to really indicate a level of development, as compared to Table 1. Table 1 could only be used to get an insight into the actions taking place in the network.

In Table 2, each level (NRL 1 – NRL7) is given a name. Furthermore, the Sufficient Condition, that has to be met before the level of development is reached, is assigned. The indicators help in indicating whether the sufficient condition is met. The Sufficient Conditions form a hard barrier for the NRL level, which means that the sufficient condition has to be met before the NRL level is reached.

Table 2 provides the opportunity to indicate the level of development of a network of interest, by using the Sufficient Conditions. If the network meets the Sufficient Condition, the according NRL level can be assigned to the network. The Product & Process indicators could help in indicating whether the Sufficient Condition is met. If a network meets the Sufficient Condition of NRL3, and NRL5, the network is assigned NRL 5, since NRL 3 is expected to be met already.

As an example the Sufficient Condition of NRL 2 is used; *The specific requirements of the project are drawn up, partner selection/inclusion has started, and the pre -conditions of collaboration are developing.* The Sufficient Condition could be further explained by using the Indicators. The pre -conditions of collaboration are explained as process indicators: trust, transparency and shared vision. The actor selection and actor involvement take place, while the specific requirements of the projects and the LOI are discussed at the same time. The vague Sufficient Conditions are explained by the Indicators. The explanation gives the user the possibility to indicate the level of development by using Table 2.

Table 2		Exploration		Concretization		Formalization		Execution
NRL		1 Triggers of Collaboration	2 Potential Network	3 First formalization of trust	4 First formalization of trust	5 Feasibility of the Project is Clear	6 Contract Signed	7 Execution Starts
Sufficient Conditions		An incentive is present to engage in a project requiring collaboration.	The specific requirements of the project are drawn up, partner selection/inclusion has started, and the pre conditions of collaboration are developing.	All potential actors are present in the network to stimulate the socio – technical project and a LOI is drafted. Collaborative interest of the actors develops.	The LOI is signed and the risks, costs & benefits are indicated, and allocated among actors based on different feasibility studies. The bigger picture of the collaboration is present.	The feasibility of the project is clear in terms of finances, and technology, which leads to the draft of a concept contract.	The network has been set -up entirely, and has final formalization in terms of a signed contract.	The network has worked together, which results in the start of the project execution. .
Indicators	Products		Actor selection takes place Actor involvement takes place (including all actors) Specific requirements of the project are drawn up Method of sharing knowledge (NDA?) discussed LOI discussed in meetings	CCA assigned Partner Selection Finished LOI is drafted Financial, Technological Environmental outline clear First allocation of tasks is made	LOI is signed Risks, Costs & Benefits indicated and allocated Economic & Technological feasibility is researched	Financial gain, or overall gain clear for actors Technology is implementable in environment Contract is drafted Risks, Costs & Benefits are allocated Tasks are divided	Contracts Signed Permits + Subsidies are obtained (and are valid)	Start of the Construction
	Process	Governmental request, or demand Potential of Financial Gain Necessity to work together External Incentives PR potential	3 preconditions of collaboration are developing (1) Trust (2) Transparency (3) Shared Vision Historical Reliability is present	Willingness to share resources & knowledge 3 Pre-conditions of collaboration present	Institutional Framework is clear to actors in the network (constraints, uncertainties, support by decision makers) Collaborative Interests + Bigger Picture of collaboration is present Management Level, or Key Actors are committed	Relation of the technology and other processes is clear Juridical department(s) involved (draft of contract)	The existence of the project is expressed in the media	Unexpected Events

6.4 Creating the NRL – Indicator

In the previous paragraph the Sufficient Conditions & Indicators –method to indicate the readiness of a of a network of actors was presented based on the third step of result analysis. In the fourth and final step of result analysis, a different methodology is proposed to determine the NRL; the NRL – indicator. The NRL –indicator is proposed because the Sufficient Conditions & Indicators method overlooks three characteristics of collaboration in a network, causing a difficulty in applying the method in practice. The three characteristics overlooked by method are introduced. After this introduction, the NRL – indicator is proposed, in combination with an explanation on the usage of the NRL –indicator. This results in **Table 3: the NRL –indicator.**

6.4.1 Three Overlooked Characteristics

The Sufficient Condition & Indicators method overlooks three characteristics of collaboration in a network of actors. The method thereby fails to provide an accurate overview of the development of the network of actors. At first, the process of network development is **dynamic**, and based on iteration. In contrast to the TRL development, which has a linear character. This dynamic character is due to progress, but also steps back in the development. Unexpected events during the collaboration might occur, that cause the development to take a step back, towards a lower level of development. For example, an LOI is signed (NRL 4), but after the signing of the LOI, an actor is replaced in the network, leading to the draft of a new LOI. As a consequence the development takes a step back, since a new LOI needs to be drafted (NRL3). Also trust, shared vision, and reliability need to develop again with the new actor. The level of development, thus could become higher, but also lower, during the development. This dynamic character is not included in the Sufficient Conditions & Indicators –method, due to the strict sufficient conditions for each level. Once a sufficient condition is met, the network is expected to maintain the level of development, which is not an adequate representation of reality. A method needs to be proposed that includes the dynamic character the network development.

As a second characteristic is that indicators of **different levels of development** will be present **at the same time** in the network. This causes difficulties in determining the exact level of development in the Sufficient Conditions & Indicators – method. A sufficient condition in the NRL –scale creates the border for the development to be indicated in a specific level. The indicators help in determining whether this is the case. There is no solution, however, for the fact that not all the indicators of the same level of development are present at the same time.

For example, trust, and transparency are experienced in a network, the LOI is drafted, and the technological feasibility of a project is clear. At the same time, the shared vision in the network is absent. Will the network be indicated in NRL 2, based on trust, and transparency? In NRL 3, based on the LOI that is signed? Or in NRL 5, since the technological feasibility of the project is already known? Based on the strict Sufficient Conditions & Indicators –method, the highest sufficient condition met, is the level of development (as is stated in paragraph 6.3.2).

The question that arises with this method is: Is such a strict structure of sufficient conditions, still valid, if many indicators of different levels of development are present at the time of assessment? Or, should a more flexible method of indication be looked at, to be able to assess the actual state of a development? The Sufficient Conditions & Indicators –method does not allow for this flexible method, therefore, this should be included in a newly proposed method.

The previous example is related to the final characteristic that is overlooked by the sufficient conditions and indicators method. The method assumes that indicators are present, or absent, but does not include the **development of an indicator** over time. The presence of an indicator could, however, be the result of a development process, spanning multiple levels of development. For instance, the development of trust among the actors is not divided into; present, or absent, but trust could be building, growing, or declining over the course of the development. The Sufficient Condition & Indicator –method does not include an insight into the development of an indicator over time. By providing a possibility to follow the development of the indicators, a more elaborate overview of the total development can be given, and a more precise assessment of its readiness.

To summarize, the method to indicate the level of development based on sufficient conditions and indicators does not include three characteristics of development. It does not capture the dynamic character of network development, provides no adequate solution for the presence of multiple indicators at the time of assessment, and does not allow an insight into the development of different indicators. In order to include these characteristics, a new method is presented in the next section; the NRL -indicator. The draft of the NRL -indicator is the fourth, and final step of the result analysis.

6.4.2 The NRL -Indicator Method

In the NRL indicator, 16 criteria that have to be present in a network of actors are presented. These criteria are selected from the results of the previous two steps of analysis; the determination of Properties, Facilitators, Barriers and of the Sufficient Conditions & Indicators. The 16 criteria function as a checklist for a more detailed determination of the NRL. The NRL –indicator turns around the method of indication that was proposed in the Sufficient Condition & Indicators -method. In the sufficient conditions and indicators method, the level of development is presented first, followed by the Sufficient Conditions & Indicators to assess the readiness of the development.

In the NRL –indicator, at first 16 criteria are presented as a checklist. The criteria can then be followed throughout the 7 levels of development. As a result, assessing the readiness of a development is not done based on a sufficient condition, and indicators, but based on the 16 criteria in the checklist.

In the following section the 16 criteria are discussed based on the outcomes of the previous steps of analysis. The criteria are based on the PFB's of collaboration, therefore, more information can be found by looking at the description of the PFB's in Appendix E. In the description of a criterion, the criterion is briefly explained, and connected to a level of development (NRL 1 –NRL7).

The 16 criteria of the NRL – indicator

1. **Incentive for collaboration**

An **incentive** to engage in the collaboration needs to be present. The incentive could be given by; a request by the government, or demand by the government that triggers actors to engage in project concerning renewable energy development. This incentive could also be provided by the perceived financial gain that a project in a collaboration brings. Besides the financial gain, the gain of the project could be in the PR –value of a renewable energy project, or coming forward from the sustainable gain that the project brings in terms of CO2 reduction. Finally, the incentive could come forward from the necessity to work together for actors, because the idea exists that the project cannot be conducted alone. The incentives for collaboration are further discussed in Appendix G. An incentive to engage in a project should be present in NRL 1, the actors should understand that engaging in a project could present benefits.

2. **Trust**

Trust is a soft variable, and a process property of the network of actors. A distinction between historical trust, and trust based on anticipation is made. **Historical trust** is expected to be present from NRL1 on until the end of the collaboration, with formalization steps in between. This trust is based on previous collaborations between the actors. New collaborations, however, do not support this historical trust. Therefore, t**rust based on anticipation** is expected to grow in NRL2, due to the partner selection, and actor meetings to tune expectations, and create a shared vision. In NRL 2, the first discussions on the formalization of trust start, the draft of a LOI takes place in NRL 3. The trust is formalized for the first time in NRL 4, by signing the LOI. This formalization is proof of the ability to form expectations about aims of the network (Appendix E.1). When the actors' future behaviour, for whatever reason, is not related to the expectations about the aims, the trust could disappear, and new effort is necessary to gain new trust. This returns the level of development to NRL 2.

3. **Transparency**

Transparency in the collaboration has to do with the openness of sharing information among the actors in the network, and is therefore a process property. During the first meetings in NRL 2, the transparent behaviour needs to be displayed, in combination with the growth of trust, and the creation of a shared vision. Along with the draft of the LOI, all useful information that could potentially be present at that stage should be present in NRL 3. Transparency is not only needed before the draft of the LOI, but also in the following feasibility studies, the potential second LOI, and the final contract in the following levels of development. The withholding of information, or the opportunistic behaviour by actors removes transparency, causing the NRL to return to NRL2.

4. **Shared Vision**

Shared Vision is hard to indicate, because this resides in the shared ideas between the actors, and their understanding of these ideas. The shared vision can be seen as a process property. If there is a mutual understanding, and a clear idea of the goal of the project, one could say that a shared vision exists. Shared vision is not present from the beginning of the network, but must be created during the first phase of development. The shared vision must develop in NRL 2, when the partner selection and meetings take place. In NRL 3, the shared vision needs to be present to work towards the signing of the LOI. Opportunistic behaviour, and not acting in alignment with the shared vision causes the network to return to NRL 2.

5. Partner Selection

Partner selection, and actor involvement needs to take place at the beginning of the collaboration to include all actors potentially involved. If all the actors in the network are present, this is a product of collaboration. All actors need to be present when the first formalization of trust (the LOI) is signed. Although not all the involved actors will sign the LOI, all actors need to have been involved. In NRL 2 the partner selection is ongoing. In NRL 3 the partner selection needs to have been finished. When partners leave the network in a higher level of development, the NRL returns to NRL2, because new partner selection needs to take place. An important remarks needs to be made on partner selection and partner involvement. Due to the socio -technical characteristics of the projects researched, many actors could be involved in the network that are not considered partner. One could think of residents in the area surrounding a wind turbine, or the users of a district heating network that are represented by a housing corporation. To indicate that partner selected has been finished, **all** potential actors involved in the network should have been indicated. A way to measure this is that all the actors must have had the opportunity to express their opinion and interest, by inviting them to the table, organizing walk – in events, and making the project known in the surrounding area.

6. Reliability

In order to indicate the presence of **reliability** in the network, two stages are present. At first the historical reliability of an actor based on previous performance becomes apparent during NRL2, because of partner selection, and first meetings. This historical reliability is based on performance in comparison with historical trust, which is based on feeling and experience in the previous collaboration. After NRL 2, the historical reliability deteriorates, and is replaced by performance reliability, based on the current collaboration. The performance reliability, therefore, grows after the first actions, and meetings, and is present in NRL 4. Here the actors must have shown their knowledge, skills, more importantly their anticipation, and adaptation to unexpected events, leading to the emergence of performance reliability (Appendix E.1). If NRL 4 is reached, but doubts on the anticipation, or adaptation of actors to unexpected events are present, the performance reliability disappears. The NRL returns to NRL2.

7. The 'Bigger Picture' of Collaboration

The **bigger picture of collaboration** is based on understanding that the collaboration is about more than personal interests, and financial gain. The 'Bigger Picture' is the idea about what developing the socio –technical system could bring forward for the actors involved, and society, not based on own interests. The bigger picture of collaboration needs to be present in NRL 4. The 'Bigger Picture' of collaboration is considered present when the following three sub -criteria are displayed by the actors in the network; **the alignment of interests, the willingness to share resources, and the same finale image.** The alignment of interest, and the willingness to share resources arise in NRL 2, based on the trust, reliability, and transparency in the actor meetings. The same final image emerges through a shared vision on the project. The 'Bigger Picture' of the collaboration is further seen as connected to the commitment of the actors. Once the 'Bigger Picture' is present, the actors are committed to the development. This must be shown in NRL 4. If the commitment is not shown after NRL 4, because of lack of involvement, conflicting interest, and an individualistic attitude, the NRL goes back to NRL 2.

8. Management, or Key Actors Involved

The **management, or key actors** are expected to be informed about the collaboration in NRL 2, since the partner selection takes place. In NRL 3 they are expected to be familiar with the network and up to date with the development of the project. In NRL 4, the management, or key actors are expected to be committed to the development. This is because authorization is needed to sign the LOI in NRL 4, and the formal contracts in NRL 6. Involving the management early means commitment from an early point in the project, preventing later on authorization barriers.

Since the authorization to sign the contract is needed later on in the collaboration again (NRL 6), the management must be informed on the project between NRL 4 and NRL 6. If this is not the case, the authorization is expected to be absent.

9. Letter of Intent (LOI)

The **LOI** is discussed from the moment that the actors are together, due to partner selection/involvement, and the building of trust, reliability, and shared vision begins. This is in NRL 2. There is no physical LOI present yet, due to the discussing phase, but there could be discussion on how information is shared, and a possible NDA could be drafted. In the NRL 3, the first LOI is drafted based on the discussions in the phase before. The draft is reviewed by all actors involved. In NRL 4, there is a signed LOI present. This signed LOI means that trust, transparency, shared vision and reliability are expected to be present in the network. Any developments influencing the validity of the LOI, such as; partners leaving the network, or disagreement among actors, leads to a return to NRL2. During the collaboration multiple LOIs, or other Collaboration Agreements might be needed, showing an iterative process. The NRL is considered to be at NRL2, when new discussion are needed, at NRL3 when a new LOI is drafted, and at NRL4, when a new LOI is signed.

10. Central Coordinating Actor (CCA)

The **Central Coordinating Actor** is appointed by the different actors in the network, right after the partner selection has been finished. In this way the central coordinating actor is able to orchestrate the network, and function as connector. The central coordinating actor is, therefore, appointed in NRL 3, and is absent in the first two NRL's. There is a difference between a central orchestrating actor appointed, and a central orchestrating actor active. The central orchestrating actor needs to be active in NRL 4, to facilitate the further development. If a CCA is appointed, agreements on the allocation his/her costs among the actors, and the role of the CCA are expected to be present.

11. Support by Decision Makers (Political)

The **support by political decision makers** is a potential facilitator, and the absence a potential barrier of collaboration. The political support, and rules & regulations should provide a level playing field for the socio –technical system, by providing a framework and the boundaries in which the development takes place. In NRL 4, this level playing field must be known. In NRL3, the level playing field of the collaboration should be researched already. This means knowledge on rules & regulations, but also on the possibility of subsidies must be brought in, supplemented with the knowledge of whether the decision makers are supporting, or hindering the development. This support could be expressed by a leading role of a decision maker, but also by a governmental authority that issues permits for the project. The support by decisions makers must be known to prevent superfluous investments, due to non -supportive decision makers. Future change of regulations, or change of decision makers influencing the development, lead to a return to NRL 3.

12. Technological Feasibility & Technological Implement ability

The **technological feasibility** of the project becomes clear spread over different levels of development. In NRL 3, the initial feasibility studies are conducted, since they coincide with the draft of the LOI. The ideas about the implementation of the technology need to be made concrete, since actors agree to look for the technological potential of the project, by signing the LOI. In NRL 4, the feasibility studies on the technological implementation are executed. In the following NRL 5, the technological implement ability should be known. In NRL 6, the calculations on the technological implementation need to be at 10% accuracy, showing the technological potential of the project. This is because the formal contracts will be drafted, and the technological potential needs to be clear.

13. Business Case Draft

Simultaneously with the pre -calculations, a **potential first business case** is drafted in NRL 3. This should provide an insight into the financial side of the collaboration, but could be limited to rough estimations of the business case. In NRL 4, the actual calculations on the business case take place, including the information on technological feasibility, and the knowledge on the level playing field of rules & regulations. In the NRL 5 a potential positive/negative business case needs to be present. Any unexpected events; lowering electricity price, less roofs available, other wind turbine types, could lead to a return to NRL4.

14. Tasks Allocated

A **clear division of tasks** is needed in the development.. At first, to prevent double work, but also to prevent ambiguity among the actors on each other's tasks. In NRL 3, an overview needs to be present of the tasks that are there to be divided over the different actors in the network. The first division of tasks is agreed upon by signing a LOI. The tasks are divided in NRL 4, due to the feasibility studies that are taking place. Each actor researches the potential, and knows its tasks for the future project. Based on the outcomes of the technological feasibility, and the business case calculations, the tasks of further collaboration need to be allocated in NRL 5. The different actors know what is asked in the further project. In NRL 6, the allocation of tasks leads to actors taking responsibilities by showing their commitment, and the actions being taken towards the formal contract.

15. Risks, Cost & Benefits[8] are allocated

The **allocation of Risks, Costs, & Benefits** is connected to the division of tasks, the technological feasibility of the project, and the draft of the business case. Therefore, a first not-binding allocation of risks, costs & benefits is present after the LOI is signed in NRL 4. During NRL 5, the RCB's become clear based on research on technological, and economic feasibility in this level. The outcome of determining the RCB's are input for the draft of the contracts in NRL 6. In NRL 6, the Risks, Costs & Benefits are recorded in the contract.

16. Formal Contracts

The **formal contract** is a criterion of the NRL, and can be split over three levels. The contract negotiations in which the parties discuss the terms, finances, and allocation of tasks in NRL 5. The draft of the contract in which the legal department of the actors draft the contract based on the outcomes of the negotiations, in NRL 6. The signing of the contracts, in NRL 7. The signing of the contracts in NRL7 is assumed to be connected to the start of the execution of the project. There could, however be a time period between the signing of the contract and the execution, due to additional studies, unexpected events, or the final tasks in the network. This has to be taken into consideration.

6.4.3 Table 3: The NRL -indicator

Based on the previous descriptions of the 16 criteria present in a socio –technical system, Table 3: the NRL –indicator is drafted. In the table, the Dark Blue colour is used when a criterion is present in the network, where the Light Blue colour indicates development of the criterion. A criterion that is present, is expected to stay present, until the next indication of the level development. If the criterion disappears from the network, the text that is presented right after the Dark Blue colour tells what happens next. The table can be used by following the roadmap of the NRL –indicator, which will be presented in paragraph 6.4.5.

[8] [13] In Table 3: The Bigger Picture of Collaboration is based on three sub- criteria: 1. The Alignment of Interests, 2. The Willingness to share Knowledge & Resources, 3. A Shared Final image of the collaboration. Once these three are present, the 'Bigger Picture' is present.

6.4.4 The use of the NRL -indicator

In this section the use of the NRL -indicator is explained. In the NRL –indicator, the 16 criteria are presented in chronological order down on the y-axis. The levels of development are presented on top of the table (x-axis). The criteria are presented in chronological order, since this gives the opportunity to follow the progress of the development from start till end. The chronological order of the criteria is determined based on the interviews conducted in this research. The assessment of the readiness of the development with the NRL -indicator should start at the first criterion ((1) Incentive). The user should determine whether the first criterion is present in the network. The criterion is present in the if the cell at which the x-axis and y-axis cross is Dark Blue. If this is the case, the next criterion ((2) Trust) needs to be checked. By following all the criteria down, an overview of which criteria are present in the network and which are not can be created. Whenever a criterion is not present, the user could look for whether the criterion is absent, developing, or whether the criterion was present in the NRL –indicator, but events caused the criterion to disappear.

At every criterion, the user of the NRL -indicator could reason why the criterion is present/absent, and what needs to be done to include the criterion. In this way, the NRL –indicator is able to assess the readiness of the network of actors based on the criteria that are present. The NRL -indicator provides a level of development based on the NRL - scale. Furthermore, the NRL –indicator is able to present an advice on which criterion needs extra effort in order to include it in the network. The NRL -indicator does not only provide an assessment based on level of development, but also provides an advice, or remark on where the network lags behind. This advice is based on the criteria that are not met in development yet. In assigning the level of development the following statement can be used:

*The level of development is based on the level of the **final criterion** (started from criterion 1) that is present in the network at the moment of assessment, and the **remarks on what criterion is lagging behind, and where extra effort** is needed, to develop the socio –technical system further.*

By using the statement of the NRL -indicator, the NRL -indicator provides a state (in terms of the NRL 1 – NRL 7), and a diagnosis on where more effort needs to be put to stimulate the further development of socio –technical system (in terms of the remarks on what is lagging behind).

An example is given to clarify the statement. If in a network, the Management/Key Actors are involved, but not yet committed to the network of actors. Furthermore, the Bigger Picture of the collaboration is present, and the LOI is drafted, but not signed yet. The level of development that can be assigned is NRL 4, based on the fact that the Bigger Picture is the final criterion present. There needs to be a remark, however, on the fact that the LOI is drafted, but not signed yet, and the management is involved, but not familiar, and committed to the network yet. This has to be done, since these criteria are following the Bigger Picture in the NRL –indicator, and are not present.

The final outcome of the example is: the level of development of the network is NRL 4, the network of actors, however, lags behind on the fact that the LOI is drafted, and not signed, and that the management needs to become committed. These criteria have to be included in the network in order for stimulate the development of the socio -technical system.

To make use of the NRL -indicator, a comprehensive roadmap is presented in 6 steps in the following paragraph.

Criteria	NRL							
Table 3	1	2	3	4	5	6	7
(1) Incentive	Incentive is present						
(2) Trust	Historical Trust Present	Trust Grows	Trust Exists				
(3) Transparency		Transparency Displayed	All information known	*Withholding / Opportunistic Behaviour Brings back to NRL2			
(4) Shared Vision		Meetings to create shared vision	Shared Vision is Present	*Opportunistic Behaviour Brings back to NRL 2			
(5) Partner Selection		Partner Selection Ongoing	Partners Selected + Actors Involved	*Partners Leaving the Network Brings back to NRL 2			
(6) Reliability	Historical Reliability Present	Performance Reliability Grows	Performance Reliability Grows	Performance Reliability Present	*Not anticipating, or adapting to unexpected events Brings Back to NRL 3		
(7) Bigger Picture + Commitment		Bigger Picture not present	Bigger Picture Develops	Bigger Picture is Present[13]	*Lack of involvement, conflicting interests, individualistic behaviour Brings back to NRL 2		
(8) Management/ Key Actors Involved		Management & Key Actors Involved	Management & Key Actors Familiar	Committed (+ Authorization Present)	Management & Key Actors Informed on Progress	Authorization Present	
(9) LOI		Discussed (+Potential NDA)	Drafted	Signed	*Developments leading to invalidation of LOI; Actors Leaving, Disagreement on (Costs, Risks) Brings back to NRL 2		
(10) CCA			Appointed	Active			
(11) Support by Decision Makers			Level Playing field researched	Known Level Playing Field	*Change in: Regulations or Support by Decision Maker Brings back to NRL 3.		
(12) Technology Feasible & Implementable			Pre –calculations of technological feasibility	Technological Feasibility Researched	Technology Implementable (+in environment)	+-10% Accurate Calculations Present	
(13) B.C. Drafted			First Sketch of B.C.	Calculations	Positive/Feasible B.C.	*Unexpected events influencing the B.C. Brings back to NRL4	
(14) Tasks Allocated			Indication of Tasks (in LOI)	Tasks are divided	All tasks are allocated	Responsibilities are taken	
(15) Risks, Costs & Benefits are divided				(Not-Binding) Allocation of RCB	Clear RCB for input in the contract	Recorded RCB	
(16) Contracts				Contract Negotiations	Draft of the Contract	Contract Signed	Execution of the Project

6.4.5 NRL -indicator Roadmap

Roadmap to use the NRL –indicator

The roadmap can be used to indicate the readiness of a network of actors with Table 3: the NRL –indicator. The readiness is expressed by using criteria to indicate a level of development and a remark on where the network lags behind in its development. In the NRL –indicator, three stages of development of a criterion are present: Absent, Developing, Present, indicated with the following colours:

Absent = White
Developing = Light Blue
Present = Dark Blue

The roadmap consists of (6) steps that have to be followed to assess the readiness of the network of actors on a numerical scale:

(1) Start at the top left with the first criterion:
- Criterion Present: Next Criterion
- Criterion Absent*: Step 2 of the Roadmap
- Criterion Developing: Step 3 of the Roadmap

(2) Reasoning based on two questions:
- Why is the criterion absent in the network that works together in the socio –technical system?
- What can be done, or what is needed to include the criterion in the network? (Potential input for this is the short description in paragraph 5.4.2, and Appendix E)
- When finished continue to step 4

(3) Reasoning based on two questions:
- In what level of development is the developing criterion, based on Table 3?
- What needs to be done to make the criterion present?
- When finished continue to step 4

(4) Continue the search for criteria down until all the 16 criteria have been indicated to provide a total overview of the development.

(5) Determine the NRL based on the Final Criterion that is present the development (in dark blue), in combination with the remarks on where the development lags behind, and needs extra effort (in white when absent, in light blue when developing), based on the following statement**:

*The level of development is based on the level of the **final criterion** (started from criterion 1) that is present in the network at the moment of assessment, and **remarks on what criterion is lagging behind, and where extra effort** is needed, to develop the socio –technical system further***.*

(6) The NRL of the network of actors is determined, based on the Roadmap. The method could be repeated monthly to create an insight into the progress.

* A criterion could also be absent, because it disappeared from the network, due to events influencing the development. This is the case when after the Dark Blue cell, there is an explanation on what happens to the NRL. In the cells, different reasons for the absence are given. An * is present in the cells to indicate them.

** There is no strict method to articulate the final outcome of the roadmap. The following statement could be used: The readiness of the network of actors can be assessed with NRL (#), the collaboration needs extra effort at (Criterion #, and Criterion #), since these are not met when indicating the level of development. These criteria have to be included in the network in order to develop the socio -technical system further.

*** The number of criteria that have to be mentioned in the remarks is decided by the user. A possibility is to include a remark on all the criteria that share the same NRL as the final criterion .

Chapter 7

Discussion

In the previous chapter of this thesis the results analysis was presented leading to the draft of the NRL –indicator. The discussion on the research is presented in this chapter. The discussion is divided into two parts. The first part presents a discussion on conducting the research in general. The second part presents a discussion on the NRL –indicator method.

7.1 Discussion of the Research

Two different parts of the conducting the research are discussed. The first part is the method of research that was used in this thesis. The second part is the validation that is needed for the outcomes of the research.

Methodology

The research methodology of using semi –structure interviews in combination with a sorting exercise provided a good insight into the factors of influence on a socio –technical system. Some points of improvement are, however, present in the research. The use of coding classes in the sorting exercise of the facilitators & barriers caused a difference in the results. Only the coding classes received an average sorting value in the sorting exercise of facilitators & barriers, whereas for the properties all individual properties received an average sorting value. Besides this, the introduction of the coding classes caused confusion among the respondents, because it was not immediately clear that the coding classes had to be ranked, and the individual facilitators and barriers had to be mentioned. By using the coding classes in each sorting exercise, or not using the sorting exercise at all, the results in future research should become equal.

Respondents further mentioned that the number of factors presented in the sorting exercises was too large, which made the exercises difficult. The number of properties was 15, the number of facilitators 22, and the number of barriers 26, which caused a difficult task for the respondents. The factors were determined based on literature and the previous NRL research of Krijger, but no limit to the amount of included factors was set. The overall amount of the factors should have been less, and the same amount of factors should have been used for all factors. This would have made the exercises easier, and would have provided a better structure. The same holds for the different number of coding classes that were used for sorting exercise of the facilitators (6), and for the sorting exercise for the barriers (5). The number was different duc to the coding class of Geography that was not included in the barriers' sorting exercise.

The number of coding classes should have been the same to provide a better structure, and equal results in terms of the chosen coding classes. Respondents asked repetitively why there was a difference in the coding classes. The answer to this was, that in the literature, multiple sources presented the influence of the geographical factors on a network (Hauber & Ruppert-Winkel, 2012; Ruppert-Winkel et al., 2016; Späth & Rohracher, 2010). Based on this insight the coding class of Geography was included, but could have been left out. Overall, the structure of the sorting exercises could have been better by leaving out the coding classes, by using the same coding classes, or by presenting the same amount of factors in each exercise.

A potential solution could be to apply the Q-sort methodology, and not use a derived version. The Q-sort asks for a predetermine P-set, and Q-set, and a statistical analysis of the results (Exel & Graaf, 2005). This would, however, take away the idea of combining the expert opinions with the outcomes of the sorting exercise, which is what is aimed for in this thesis. Using the Q-sort methodology would, however, cause more structure in the sorting exercises.

The sorting exercise used could have been more focussed on placing the factors in the right level of development. The used exercise only asked the experts to rank the factors, but did not ask them to place the factors in a level of development. The level of development in which the factors were present was discussed in the motivation of the ranking. The place of the factors is arbitrary, since it is based only on discussion. An additional exercise could have been presented, asking the experts to place the chosen factors of influence on an empty NRL –scale. This provides an extra insight into the right connection between factor and level of development, making the NRL –scale more realistic. Krijger proposed a method in which his respondents placed the barriers on an empty scale. This exercise, however, did not result in useful data in his research. The exercises was not included in this research. Another reason not to include this placing exercise was because the ranking of the factors was already a difficult and time consuming task for the respondents.

Besides the different structures of the sorting exercises, the limited heterogeneity among the experts, had an impact on the outcomes of the research. The experts for the interviews came forward from the cases of Tata Steel IJmuiden . A total of 15 experts were interviewed. There is, however, no indicator of the minimum number of experts needed. The final number was based on the availability of the experts in the cases. Of the 15 experts, 8 experts were internal Tata Steel actors (of 1 interviewee the results are not used), and 7 were external actors, leading to a total of 14. Of the external actors, 5 were involved in a governmental organization, or interest group, only 2 were involved in other (semi -)commercial parties. This makes the outcomes of the research Tata Steel and government motivated. The private sector is simply underrepresented, which could threaten the reproducibility of the research. It could be that a collaboration between only private actors in influenced by different factors, than the collaboration between private and public parties that were analyzed in this research, resulting in a different draft of the NRL -indicator. On the other hand, the respondents were present in three different cases, making them diverse in the sense of case diversity. The actors represented the same type of organizations, but all in another context, creating the diversity that was looked for. A different possibility to solve the limited diversity in future research is by trying to divide the number of interviewed actors equally over different backgrounds, such as: internal actors, external governmental actors, external private actors, and other actors involved.

Validation

The new theoretical framework developed in this thesis needs application, and validation. The theoretical framework was drafted since the framework used by Krijger was rather thin, and had a different focus. This caused the framework of Krijger not to be applicable in this research. A new framework on the development of a network of actors in a socio -technical system was drafted based on different sources from literature. The framework combines the stepwise process of development, and the factors of influence that were proposed in literature. No validation of the framework has been done yet. Based on this fact, the decision was made to only use the coding classes in the sorting exercise and not use the framework to structure the research. The theoretical framework is a first proposal of a structure that could be valuable because no other framework exists in literature. Validation of the framework, however, is needed.

Validation of the NRL – indicator is needed, due to the pioneering characteristic of the methodology. In this research, interviews were conducted with actors involved in a wind park, a solar panel project, and a DH –infrastructure. This means that the three projects were all related to the generation, or usage of energy. The three projects, however, are very different from each other in terms of the actors involved, and background. In the wind park project, multiple governmental actors are present, environmental advisory firms, licensing authorities, but also local residents impacted by the new wind park. In the solar panel project on the contrary, only the developer of the project, and the client were involved, impacted by the SDE+ subsidy. In the DH -infrastructure project the supply and demand side of the network had to be connected, influencing the suppliers, developers, governmental organizations, and housing corporations in the heat supply chain. The different actors involved, and backgrounds of the cases, made creating a methodology hard, since the insights of three totally different networks had to be included. The created methodology thereby becomes rather general, and maybe not applicable to certain cases, since case specific factors are not included. On the other hand, in combining the insights of three different cases, the applicability of the methodology becomes wider in terms of the types of networks.

The idea of a general application of the NRL -indicator, asks for a validation. A method to validate the tool is by using the tool to indicate the readiness of a network of actors in socio -technical systems, with different backgrounds: renewable energy, pharmaceutical industry, construction, innovation networks, or public-private partnerships. If the NRL –indicator is applicable in different types of networks, the indicator could be validated based on a broad applicability. A second method to validate the NRL -indicator is by using an expert validation. In this validation method a predetermined group of independent experts is asked to provide their opinion on the applicability of the methodology. If experts from different backgrounds are gathered, the diverse application of the NRL –indicator could be validated. This expert validation would provide an insight into the value of the NRL –indicator, but could also give an insight into where the methodology fails, and needs improvement. Since the NRL -indicator is not applied, or validated in this thesis, the reader might be left a little frustrated in the end. A new methodology is proposed, but there is no insight in the functioning of the methodology. The expert validation needs to be organized to show the value, and the functioning of the NRL -indicator.

Finally, when reflecting on the addition of this research to the existing literature, some insights are obtained. In literature on socio -technical systems, different theories are present that describe transition in the systems on a high level of analysis, such as the national, or system level. The multi -level perspective introduces the landscape (macro) , regime (meso) , and niches (micro level) to describe a socio -technical transition from a macro level. The influence of the meso, and micro level are described to explain the changes in the landscape (Geels, 2002; Verbong, 2010). The Transition Payways introduce four pathways to describe a socio -technical transition from a high level of analysis (Verbong, 2010; Geels, 2007; Geels, 2016). Also in the publications on Transition Management, the scope of analysis is the whole society, or the actions by the government to steer a transition (Rotmans, 2001; Kern, 2009). A similar idea of the whole system as the scope of analysis is present in Technological Innovation Systems (TIS) (Markard & Truffer, 2007). All the theories present methods to describe a socio -technical system in transition, and present examples of these systems. They surpass the fact, however, that once a change in a socio -technical system occurs. On the lower level of analysis, different small scale networks of actors are contributing to the change in the socio -technical system by developing, or managing the technical system, through building new wind parks, solar panels, or creating a district heating network. In this sense this thesis adds to theory, by making this lower scale of analysis present by proposing a scale to monitor the development on this lower scale of the socio -technical system.

At the lower level of analysis, such as Innovation Networks, and Regional Energy Transitions, different publications are present describing the factors of influence on a network of actors. The publication do not, however, indicate the development of a network in the way the NRL -indicator does. In a research on the regional energy transition in Germany, a set of influencing factors was validated by a number of respondents. This lead to a diverse pattern of factors of influence on the transition, but no clear method to structure these (Lutz, Fischer, et al., 2017). A different study on a regional energy transition showed the important role of central actors, commitment by the region, and subsidy schemes to contribute to the transition, but did not connect the actions to a stage of development (Späth & Rohracher, 2010). The 3 -Phase -Model (3PM) of the energy transition presented different actors, and artefacts to be present in different stages of development. In the study, however, no numerical levels were used to indicate the development (Hauber & Ruppert-Winkel, 2012). The connection of factors to a stage of development was repeated in works on Innovation Networks by Hekkert. Different Functions of Innovations become important in different stages of development. The Functions of Innovations could be found out by conducting expert interviews, and analysing the results (Hekkert, Marko ; Heimeriks, Gaston; Harmsen, 2011). The publications at the lower level of analysis, present the idea of connecting factors of influence/actions to a stage/phase of development. The NRL -indicator could add to theory since its presents a clear methodology to assign a numerical level of development to a network, which is not present in the literature at the moment.

In conclusion, one could say that the NRL -indicator makes a contribution to theory at the lower level of analysis, by concretizing the processes that are going on in the social dimension of a socio -technical system. The NRL -indicator concretizes this by presenting the processes, and connecting them to a numerical level of development. On the other hand one could say that the NRL -indicator should be changed and applied to a higher level of analysis, to have serve as a contribution to the theory on socio -technical systems and transitions. This recommendation is made in paragraph 8.2. The fact that the NRL -indicator contributes to both the lower, and the higher level of analysis should have been the gap in literature in the literature study of Chapter 4. The literature study was, however, focussed on finding a new theoretical framework, due to the absence of one in the works of Krijger.

7.2 Discussion on the NRL -indicator

The Three Characteristics Included in the NRL –indicator

In paragraph 6.4.1, three characteristics that were overlooked by the Sufficient Conditions & Indicators method were presented; the dynamic character, indicators of different levels of development present at the same time, and the development of the indicators that span multiple levels. The characteristics are included in the NRL –indicator. How the three characteristics are included in the NRL -indicator is discussed in this paragraph.

At first, the NRL –indicator includes the **dynamic** character of network development. It does so, by providing the opportunity to follow a criterion from a lower level of development to a higher level of development, and vice versa. The NRL –indicator shows how a criterion develops, but also where its level of development falls back to, if the development is negative. In this way the NRL –indicator includes the dynamic character of network development, and gives a better representation of the collaboration.

The NRL -indicator does not provide a solution for the negative development, or on how to include a criterion in the network again, but invites to think about what could have caused this, and how it could be solved. The tool is only an indicator, and a checklist, and not an advisory tool in problem solving. The repetitive use of the NRL -indicator allows for monitoring the dynamic character of network development, and indicating a step back in the network easily.

The second characteristic included, is the fact that **indicators of multiple levels of development are present at the same time in the network**, making the indication of the level of development hard. The example of paragraph 6.4 in combination with the sufficient conditions and indicators method is given to provide clarification. The example*: In a network Trust & Transparency are experienced among the actors. Based on this the LOI was drafted, which places the network in NRL 3 (according to the Sufficient Conditions & Indicators method) Besides this, the technological feasibility of the project is known, which is an indicator of NRL 5. At the same time, the shared vision concerning the goal of the project is absent, because some actors are only looking at financial gain, others look for PR value, while the goal of the collaboration is a cleaner environment. This causes in the sufficient conditions and indicators method that the sufficient condition of NRL 3 is not met, and the network is indicated with NRL 2.*

By using the Sufficient Conditions & Indicators method, it is hard to indicate the level of development in the example, since indicators from different levels of development are present. A choice has to be made on whether the Sufficient Condition of NRL 3 is a hard barrier, because the Shared Vision is still absent, or a soft barrier, since Trust and Transparency are present.

The NRL -Indicator on the other hand facilitates an easier answer: the level of development of the network is NRL 3, and the collaboration needs extra effort to create a Shared Vision, since this is not present among the actors. This has to be included in the network in order to develop the socio –technical system further. Hence, the NRL -indicator helps in determining the level of development, but also indicates what is lagging behind in the network, and what needs extra effort. The NRL –Indicator thereby provides a hands on solution for indicating the level of development, and the problem of multiple indicators present at the same time.

Finally, the **development process** of a criterion is included in the NRL –indicator. This allows for a more elaborate indication of the NRL, because the development of a criterion is presented, instead of only reporting that a criterion is present, or absent. As an example, simply stating that the LOI is signed (NRL 4), and not present (all other NRL's), is too limited to allow for a practical assessment of the NRL. The NRL –indicator present the Discussion (NRL2), Draft (NRL3), and Signing (NRL 4) of the LOI.

By providing the opportunity to follow the criteria throughout the development process, the NRL -indicator determines the level of development based on individual criteria, instead of using general sufficient conditions, and indicators. Following the criteria gives a less concise indication of the level of development, since all the criteria need to be checked to form an image, but allows for a more precise indication of the readiness of the network. The individual criteria better indicate what is developed well in the network, and what is lagging behind. In a practical application, more emphasis can be put on the criteria that are lagging behind in the network of actors. This is the difference between the NRL –indicator an the already existing NRL of Krijger. The works of Krijger presented the PFB's in Table A and Table B[9] based on the Sufficient Conditions & Indicators to assess readiness, but stopped here. He did not include a practically applicable indicator and a description of how this indicator could be used. The works of Krijger present a first idea of the NRL –scale, which is further worked out in this research.

Furthermore, this thesis proposes a new theoretical framework that could form the basis of the research (once validated), potentially replacing the framework of Krijger. Besides the theoretical motivation, the NRL –indicator presents a larger number, and wider range of factors of influence on the development. Finally, the thesis presents a method, the 4 step method of result analysis, that could be used to structure the results of a research, and create a NRL –scale. This method was not present in the research of Krijger.

The application of the NRL -indicator

The NRL –indicator could be used as a management methodology for actors in a network, to temporarily assess the readiness of the network of actors they are engaged in. The changing character of the network of actors asks for a temporary, but repetitive indication of the level of development. This indication shows the changes that occurred, and helps to see where extra effort needs to be put in the development of the network. Using the methodology on a monthly basis, could be a starting point. The user of the NRL -indicator starts each indication at the top left, and follows the criteria down. This means that on a monthly basis, the presence of all the criteria is checked again. The user gets an insight into whether the development has stayed the same, has progressed, or has made a step back, based on the criteria that are met in the indicator.

Besides this, the presence of different criteria is necessary throughout the collaboration. For example, sharing of information, transparency, trust, and shared vision in the network need to remain present. The repetitive character of the NRL -indicator makes sure that these criteria are checked on a monthly basis, which helps in indicating if a network is still working well together, or whether different criteria have disappeared, and need extra effort.

[9] Table A and Table B are explained in Chapter 3.1.1.

The use of the NRL -indicator could be time consuming, where it is should be easy, and fast. By looking at all the criteria from top to bottom on a monthly basis. The user of the indicator looks at everything that has happened in the past. One could argue whether it is necessary to look at all the criteria every time the NRL -indicator is used. Question is if there are methods that would make the use of the NRL -indicator less time consuming. Some examples of using the NRL -indicator differently are:

- Continue from the last criterion that was present the last time the NRL -indicator was used, without looking at all the criteria from the top. This implies that the user takes the previously met criteria as being present in the network, and focusses on the future development. This saves time, because not all the criteria have to be checked. A negative side is that the criteria that have disappeared from the network as compared to the previous month are not noticed when using the NRL -indicator. The user gets an inaccurate image of the network.
- Only use the Dark Blue Cells in Table 3. Nearly all Dark Blue Cells that are underneath each other share the same NRL. This means that in checking only whether the Dark Blue Cells are present, the user could get an image of the network, without all the information in the Light Blue and White Cells. The user takes a 'snapshot' of the network every time the NRL -indicator is used and compares the difference between the monthly snapshots to see what has changed. All the information on the past development of the criteria, and the future developments could be neglected. This makes the NRL determination swift, and the indicator easier to use. The Light Blue and White Cells surrounding the Dark Blue Cells could function as background information to the development of the network, but do not play a role in the determination of the level of development.
- Start at criterion 16, and go up to criterion 1. The first criterion that is present in the network is the NRL that should be assigned to the network. This is a reverse reasoning from the method proposed in the NRL -indicator Roadmap, but could provide a shorter process. If a contract is signed already, NRL 7 could immediately be assigned to the network without checking all the criteria from 1 tot 16. The user does not have to check all the criteria from top to bottom. The same, however, in the method starting at criterion 16 for a network in an early stage of development, since all the criteria from the bottom upwards have to be checked.

An important question that needs to be asked when using the indicator is: 'How does the user of the indicator obtain information on the development?'. If the user assesses the readiness of the development based on own insights, the outcome could be biased and subjective. In an ideal situation all the information needed is present in the network, and the assessment is done easily. To approach this situation, the NRL –indicator is not to be used by a single person, but could be used during meetings of the network of actors. The more information is present on a criterion, the more accurate the NRL –indicator could assess the development.

In an ideal situation, the use of the NRL –indicator is agreed upon at the beginning of collaboration. The NRL –indicator is used together with the other actors. Shared ideas, a shared indication of the state of the network, and a shared idea on what is lagging behind in the network, could be created. This facilitates the discussion on the collaboration, and makes different actors in the network express their needs during the meetings. By following the NRL –indicator Roadmap, the collaboration could be facilitated based on the discussion that emerges. Using the NRL –indicator with multiple actors prevents bias, and a subjective view of the development, thereby providing a more realistic image of the development.

Points of improvement in the NRL –indicator

The NRL -indicator does not present a clear indication of the level of development in a number; the NRL is 6. The NRL -indicator provides the current status of the network in combination with diagnosis on where the network lags behind. The Sufficient Conditions & Indicators method, on the contrary, does provide a clear level of development, based on the Sufficient Condition that is met. The clear level of development helps in creating an image of the development, which allows for easier communication among actors. For example, NRL 4 in the Sufficient Condition & Indicators method is indicated by a signed LOI, an active CCA, and research on the feasibility of the project. This provides clear indicators to form an image of the status of the network. The NRL –indicator, on the contrary, will always provide a level of development, combined with a remark on what needs extra effort to develop further. This leads to a less clear image of the status of the network. The practical application of both methods must give an idea of which method provides a better image of the readiness. Besides this, the practical application should give insights into which method is better applicable to networks of interest.

The fact that the NRL -indicator is not applied in a practical case yet, raises two important questions. At first: ‘ How easily is the NRL – indicator applicable?’. It is not clear whether the NRL -indicator is as easily applicable as expected. The explanation of the methodology is done in three pages, and in an ideal situation this is enough to understand and apply the tool. Besides this, there is no insight into whether checking the presence of the 16 criteria is an easy task, or whether it is very time consuming. To facilitate the use of the NRL -indicator the explanation of the criteria is short, the NRL -indicator Roadmap provides an easy explanation, and the potential benefits are explained.

The second question that arises is:’ How well does the NRL -indicator work?’. This question arises since there is no proof of the value of the NRL -indicator. It could well be that the NRL -indicator gives a wrong image of the network, or an image that is not extensive enough to get an idea of the development of the socio -technical system. The only way to answer both questions is by applying the NRL -indicator in a case that last for a longer period of time. There is no proof of application based on the works of Krijger, since he admitted that his version was not ready to be applied. This version is ready, but needs application in a future research.

One important remark should be made on the application, and the value of the NRL -indicator. The NRL -indicator provides a NRL in combination with a remark on which criterion needs extra effort in the network. The NRL – indicator does so by working with Blue, Light Blue, and White cells (see Table 3, page. 61). The NRL -indicator gives a complete idea of the development, current status, and future development of a criterion. ‘Why would you give so much attention to the development of a criterion and not provide a clear NRL?’ ‘Why not only give a ‘snapshot’ of the network?’. The answer to these questions is based on the idea that by giving information on the development of a criterion a much more elaborate idea of the network is presented. By giving an insight into the status of the network, but also what has happened before, and what could happen in the future, the user of the NRL -indicator gets a complete overview of the network studied. A criterion does not emerges out of nowhere, but develops over time. Different measurable steps in the development provide a more realistic idea of the network than just saying a criterion is present, or is absent. The more information is present in the NRL -indicator, the more realistic the image is that is obtained by using the methodology, as long as this does not affect the ease of use. To bypass the development of the different criteria. A user of the NRL -indicator could only use the Blue cells (as is proposed earlier in this discussion), when looking at a network. The Blue cells could be used to make a snapshot of the network, without the information in the Light Blue, and White cells. By repeating the snapshots, and checking whether the Blue cells are present, the user obtains an image of the network without the information from the Light Blue, and White Cells.

What has to be admitted is that one could argue whether all the criteria that are included in the NRL -indicator are actually measurable. For instance Shared Vision in a network. In the NRL -indicator this criterion is divided over Meetings to Create Shared Vision (Light Blue) – Shared Vision is present(Dark Blue). The Meetings to Create Shared Vision could be measured, since these are physical meetings that could be organized. The actual presence of Shared Vision is harder to measure, because what determines that a shared vision is present.

The fact that the actors state that they share a vision? But what is one actor thinks differently? The NRL -indicator includes criteria that are hard to measure. These criteria are therefore arguable in the NRL -indicator. The criteria that are hard to measure in the NRL -indicator are: trust, transparency, shared vision, reliability, bigger picture. These four criteria include the three pre -conditions of collaboration that were determined based on the outcomes of the sorting exercises. These soft criteria are hard to measure, but indispensable in a network of actors. These criteria need to be included in the NRL -indicator, otherwise a less complete image of the network is presented.

The 16 criteria of the NRL –indicator are determined based on the outcomes of the interview results in paragraph 5.2 & 5.3. The criteria give an overview of the factors influencing a collaboration in a network of actors. There is no certainty on whether the number of criteria is extensive enough, or whether criteria have to be removed. The number of 16 is determined based on the most important properties, facilitators, and barriers, but it could have been 18 or 20 instead. The practical application of the tool needs to provide clarity on the number of criteria that have to be included.

A potential benefit of the 16 criteria is, that the criteria could be added, or removed, depending on the type of network. This is opposite to the rigid, and pre –determined structure of the sufficient conditions and indicators method. The removal, or addition of criteria allows for changes in the NRL –indicator and makes it applicable to different networks. Just as the TRL was adapted to other sectors then aerospace engineering, by creating spin- off tools adjusted to specific market criteria (Mankins, 2009). If a specific criterion is very important for a network, this criterion can be added in a future research, to make the NRL -indicator suitable for that network. The same holds for the removal of a criterion. For example, if safety is very important in a network, or the fact that specific company rules are implied, these criteria can be added to the NRL –indicator. The addition of these extra criteria, however, can only be done under the condition that the criteria are included based on the same 4 –step method as used in this research (see Paragraph 5.1 till 5.4). Using this method of including the criteria ensures that the criteria are added based on the right motivations, and backed by data.

A more practical idea of adding extra criteria, or removing criteria, gives the user of the NRL –indicator the option to add/remove criteria. The user could add a criterion based on the importance of the criterion in the network of interest. This idea allows for a more practical application, because the NRL –indicator can be adapted to study any network. Before the NRL –indicator is used, extra criteria can be added by a single user, or by the actors in the network, based on consensus on the importance of the added criterion. This allows for a very flexible NRL –indicator, making the methodology applicable in different networks.

The order of the 16 criteria determines the level of development that is assigned in the NRL indicator. This is true in the sense that the level of development is indicated based on the final criterion that is present in the network. If a different criterion that is present would have been earlier in the order of the NRL -indicator, the level of development might have been different. This has to do with the chronological order of the criteria, which could be arbitrary. A research into the position of the different criteria in the NRL –indicator is needed to find out if the order presents reality.

As a final point of improvement, the time scope of the NRL -indicator should be mentioned. The scope of the NRL -indicator ranges from the moment an incentive is present to engage in a network of actors till the moment the contracts are signed. This means that the physical construction of the projects albeit a wind park, or solar panels, is out of the scope of the NRL -indicator. The actual addition to the socio -technical system is not included. The time scope of the NRL -indicator is deliberately chosen to only include the social interactions in the indicator, but the scope could be widened. Potentially one or two levels could be added that describe the process of construction and what factors influence the network in these levels. The addition gives a more complete overview from incentive till final addition of the small scale project to the larger socio -technical system.

Comparison of the NRL of Krijger and the NRL -indicator

A final step in the discussion is a comparison between the NRL of Krijger and the NRL -indicator. The two methodologies are compared based on: the background of the methodology, the actors involved, the projects that were used, and the theoretical background. Besides, the methodologies are compared on their potential application. The comparison should give an idea of the improvement that was made in the methodology, and the potential of the NRL -indicator.

Background of the Methodology

The NRL of Krijger is based on the introduction of innovation in a network of actors. Although he presents the NRL as a methodology to assess socio -technical systems, the scope of the NRL -scale is narrow, due to the background based on innovation. The NRL -indicator is based on low level of analysis cases of implementing a technology to add to a socio -technical system. The methodology is based on the energy system, but a much broader application of the NRL -indicator is pursued, since the methodology is based on implementation instead of innovation.

Actor Classes

The NRL of Krijger is only based on interviews with private actors involved in one network to introduce demand response. Krijger proposes a research in his discussion that includes more public sector actors, since these were not present in his research. The NRL -indicator is based on interviews with public and private actors, divided over three different socio -technical system cases (solar, wind, DH). The public actors also supported different roles such as; licensing authority, interest group, monitoring, steering group of the project. This means that a larger variety of experts was present in the draft of the NRL -indicator.

Projects Used

The NRL of Krijger is based on one project of introducing demand response in an industrial cluster. The experts were all originating from this one project. In the NRL -indicator three projects with socio -technical characteristics were researched. The characteristics of the projects were: multi -actor networks working together, social and technical dimension, multiple internal and external actors, public and private actors, projects add to the transition of the energy system.

Draft of the NRL

The NRL of Krijger was drafted based on a sorting exercise in combination with expert opinions. The NRL -indicator is drafted based on a more elaborate sorting exercise, expert opinions, and connecting the outcomes of the sorting exercise to theory. This was done in order to create a theoretical background to the chosen property. The NRL -indicator presents a more elaborate explanation of the different factors included in the methodology.

Theoretical Background

The NRL of Krijger is based on a framework for Innovation Networks. This framework presents how a central hub firm could leverage the output of the Innovation Network surrounding it, by using 5 orchestrating processes. This framework could be valuable for innovative output, but the scope is too small for a network of actors in a socio -technical system. The NRL -indicator is based on the idea that a network develops over time, and is influenced by different factors coming from four different characteristics of network development; network structure, substance, process and scale. Although the theoretical framework is only a proposal, the four characteristics provide a valuable insight into the factors of influence on a network of actors.

The potential of both methodologies

The final comparison is based on how of both methodologies indicate the readiness of the network of actors. The comparison is based on the characteristics of both methodologies. In a future research, both methodologies should be used to indicate a level of development, and the experience during both utilizations should be compared.

Characteristic	NRL Krijger	NRL -indicator
Validation of Factors in the methodology	Sorting Exercise & Expert Opinion. No connection to literature.	Connecting outcomes of the Sorting Exercise to Expert Opinions & Literature.
Type of network for the application	Innovation Networks	Socio -technical systems: transport, communication, energy systems.
Practical Application	Not possible according to Krijger, since it is only a first proposal of a methodology	Ready to use methodology is presented. The methodology needs validation & application
Indication Method	Sufficient Condition & Indicators method leading to limited detail in the indication of the level of development.	16 criteria of influence on a network of actors (with possibility to add, and remove criteria)
Outcome of Indication	Clear NRL	NLR and indication of what lags behind in the network
The development of the factors of influence	Not possible due to rigid Sufficient Conditions & Indicators method.	Yes based on the Light Blue and Blue cells in the NRL -indicator
Use of the method in a network of actors	Sufficient Conditions & Indicators method is used by one user, who applies the method to a network.	NRL -indicator is used by the network of actors to create an accurate image of the development of the network. Up front the application of the network is agreed upon.

Figure 7.1 – Table with the comparison of the NRL of Krijger and the NRL -indicator based on different characteristics of both methodologies. The characteristics were chosen based on the most important improvements that were made in the NRL -indicator.

Chapter 8

Conclusion, and recommendations

This research has looked into the creation of a numerical indicator to assess the readiness of the social dimension of a socio –technical system. Referred to as a network of actors. In order to answer the main research question: *'What should a scale to assess the readiness of a network of actors in a socio -technical system look like?,* different sub –questions were formulated. In chapter 8 of this research the main research question is answered, and the conclusion is presented. Besides this, recommendations on future research into the social dimension of socio -technical system and the validation this research are presented in paragraph 8.2.

8.1 Conclusion

To structure the research into the creation of a new methodology, a new theoretical framework was drafted for the development of a network of actors, since no framework was present in the existing literature. The drafted framework in this thesis, however, needs validation to be applicable in further research, but provided the idea that a network of actors is influenced by different factors over time. Based on the framework these factors were divided into different coding classes: collaboration, communication, political, economy, technology (and geography). In order to find out what factors further influenced a network of actors, literature was gathered on three different types of factors; the properties, the facilitators, and the barriers of a collaboration in a network of actors. Properties are the factors that have to be present, and are connected to development, like trust, reliability, shared vision, and formal contracts. The facilitators are the factors that help the network of actors further in the development, like the alignment of interests, the presence of rules & regulations, targets and goals for the development, but also the presence of subsidies. The barriers are the factors that explicitly hinder the further development, such as legal constraints, conflicting interests, and withholding of information.

The factors were brought together in three sorting exercise to be validated by experts. The sorting exercises asked the experts to rank the factors based on their importance. The results of the sorting exercises were presented in the form of a number of times chosen value and the motivation of the experts on the ranking of the factors. Based on the outcomes, the properties of; trust, transparency, and shared vision could not be missed in the development and were considered the pre –conditions of a network of actors. The political ,and economical factors created the conditions, or level playing field for the development, by both facilitating and hindering the development. Furthermore, the 'soft' factors of sharing the same image, getting familiar with the background of other partners, and a clear allocation of tasks were said to be influencing the development, and could be seen as the process factors. The structuring factors of influence, like the need of a LOI, a contract, and a CCA to facilitate the development could be referred to as the product factors of influence. The factors, however, were presented by a numerical value after the sorting exercise, and had to be changed and combined with expert opinions to assess the readiness of the network of actors. This change was made based on the 4 –step analysis of results.

The 4 –step result analysis

In the first step of the result analysis the outcomes of the sorting exercises were presented and selected based on the number of times chosen value of the individual properties, facilitators, and barriers. The selected factors formed the input for the second step of analysis in which the factors are connected to theory in order to explain the specific factors. Besides this the expert' opinions are mentioned to provide further motivation for the inclusion of the factors, and to search for more factors of influence based on the expert opinions. Table 1 of Properties, Facilitators & Barriers was the outcome, connecting the different factors to a level of development. This table, however, is able to determine a level of development, but not to indicate, or assess the readiness of a network on a level scale. Therefore, a third step of result analysis translated the selected PFBs into Sufficient Conditions & Indicators for each level of development, leading to Table 2. The method was able to assess the readiness of a development based on a predetermined sufficient condition, and connected indicators. Three characteristics the social side of a socio -technical system, however, are missing in the method; the dynamic character, the presence of multiple indicators at the same time, and the development of the indicators over time. This caused the need for a fourth and final step of result analysis. This fourth step presents the draft a new numerical scale; the NRL -indicator.

The NRL –indicator

The NRL –indicator developed in this research is a methodology to determine the readiness of the social dimension of a socio -technical system on a numerical scale. The readiness is determined based on 16 criteria, divided over 7 levels of development (NRL1-NRL7). The NRL -indicator allows for assessing the readiness of a network of actors on a numerical scale, in combination with an indication on where the development lags behind, and where extra effort needs to be put. The methodology facilitates a temporary indication of the status of the network of actors, and asks for repetitive use, by an individual actor or within a network of actors.

Three characteristics that were absent in the previous numerical indicators are included in the NRL –indicator. At first, by including the dynamic character of network development through its repetitive use, and the possibility to indicate both positive and negative development in the same scale. Secondly, multiple criteria can be indicated at the same time, providing a more elaborate overview. Finally, the NRL -indicator includes the third characteristic by showing the development process of the criteria spread over multiple levels of development.

The NRL -indicator is the final outcome of the result analysis. The methodology allows for the temporary indication of the readiness of a network, and invites for further discussion among the actors. The indicator determines the state of the network on a level scale, and indicates where in the network extra efforts need to be put, but does not propose a solution to potential problems in the network. The methodology invites to think on solutions within the network of actors, and thereby captures the potential problems that arise. Since the NRL -indicator captures the social factors of influence on a socio -technical system for the first time on a practically applicable scale. The NRL -indicator could be applied in multiple networks of actors in different socio -technical systems on a low level of analysis. The methodology could show its value in structuring a collaboration in a network of actors, creating the same image among actors, and functioning as a checklist for the factors of influence on the network.

8.2 Recommendations for Future Research

This section briefly discusses the recommendations for future research on the topic of the NRL. The recommendations are either based on the fact that they are out of the scope of the research, or came up during the research itself. The recommendations are divided into general research recommendations, and recommendations for the NRL –indicator. As a final part of this thesis, recommendations to Tata Steel are given, and a personal reflection is presented.

Overall Research Recommendations

Due to the pioneering character of this thesis, future research into the NRL has many different options that have not been discussed yet. First of all, the NRL -indicator is drafted based on renewable energy cases. It would be interesting to study socio -technical systems in other sectors to create an improved NRL –indicator. The TRL scale was drafted by NASA for technology development in the aerospace sector, but was adapted to be applicable to different sectors in later studies, such as; oil and gas, military, and the European commission. A similar idea could be aimed for in future NRL research to discover how the NRL would differ over different sectors.

The NRL is only a first proposal of a methodology. The methodology needs to be validated, and applied to be able to determine whether the methodology is useful, or even applicable in socio – technical systems/transitions. As a first option, a research could be conducted into the application of the NRL in a single ongoing project. The researcher could ask the actors in the project to apply the NRL in their projects, and share their findings. The research could show the value of applying the NRL in a long term project. Besides this, the users of the NRL could be asked to monitor when specific properties, facilitators, and barriers emerged in the project. The outcomes could be compared to the current version of the NRL to see whether the NRL places the factors in the right level of development.

In a different research, the researcher could simply assess the readiness of a single project, and ask other actors in the project to assess too by using the NRL. The outcomes could show how the interpretation of the outcomes changes over different actors, and whether a common idea of the project exists among the actors involved. A final research into the application of the NRL is by comparing the outcome of NRL indication of a renewable energy project with a construction project, or a public –private partnership, to see if there is any difference in the outcome. The same outcome could lead to a general applicability of the NRL, whereas a different outcome leads to a sector specific need of the NRL. By comparing over different sectors, there is no need to develop a new NRL –tool. The researcher only compares the outcomes of different sectors.

In the above mentioned examples the existing NRL is applied. The NRL is, however, far from developed, and research into improving the NRL is still necessary. In a future research, the number of properties, facilitators, and barriers used in the sorting exercise can be limited. The interviewees indicated that the determination of the most important properties, facilitators, and barriers was a daunting task. Partly because the sorting exercise caused the respondents to think about a difficult topic, but for the greatest part because the sorting exercise presented too many factors. This made the task for the respondent hard. The number of factors to choose from could, therefore, be reduce in a future research. The researcher, however, should think of the fact that reducing too much, causes a less complete overview of the factors influencing network development.

Furthermore, the composition of the expert group could be changed by adding more private sector actors, as compared to this research. This should give a more representative view of the socio –technical system, and the network of actors in the system. Construction companies, competitors, sub –contractors could provide a more private sector minded scope.

A differently structured research in which the respondent is asked to place properties, facilitators, and barriers in a level of development would be interesting to find out where in the process specific factors influence the collaboration. In this thesis the factors have been determined, and are connected to a level of development based on the remarks by the respondents, and the researchers interpretation. This indication could still be arbitrary, since it is based on interpretation of the remarks. By giving actors the possibility to connect pre -determined PFBs to an empty numerical scale, a better idea of where in the process the factors occur, could be obtained. The respondent is offered an empty NRL –scale, and is asked to place the predetermined factors in the scale, to find out if a general image of the NRL –scale develops. This idea was already proposed by Krijger for the barriers of collaboration, but in his research the method did not lead to specific results. Therefore, Krijger did not include the outcomes.

Research Recommendations for the NRL -indicator

A future researcher that wishes to improve the drafted NRL –indicator could look for the following things in his research. The NRL-indicator uses 16 criteria to assess the readiness of the network of actors. Future research could be conducted into whether these 16 criteria need addition, or whether some criteria need to be removed from the NRL -indicator, in order to make the tool applicable to different types of networks. The question the researcher could ask is: 'What criteria need to be added, or removed from the NRL –indicator?', but also 'Why should these criteria by added/removed?' In this way the researcher already questions to addition/removal motivating the choice, which was done in this research too.

In this research the importance of the three pre –conditions of the network, and the distinction between the product, and process indicators was made. Both these things are not directly included in the NRL –indicator. The two outcomes are discussed in the explanation of the NRL –indicator, but are not included in the final version. The pre –conditions are included, but not mentioned as such, or used as real pre –conditions that need to be present before the development could start. The product and process indicators were still present in Table 2, but removed from the NRL –indicator. This was done since the criteria are based on the order of occurrence, and not necessarily on the form in which they occur. A future research could include these two distinctions to create a more detailed NRL –indicator.

The NRL -indicator includes three characteristics of development; dynamic character, same time presence of criteria, and the development of a criterion over time, in order to make the tool resemble the reality more than the Sufficient Conditions & Indicators method. The NRL -indicator is, however, a first draft of a methodology and needs to be checked in practical cases. A first research, and application of the tool could be to use the tool in a project that spans multiple months, or at least a longer period of time. The NRL -indicator could be used in this project, to assess the level of development of the network on a monthly basis, to check whether the tool is applicable, and is capable of assigning the dynamic character of the network development. In one month the network could exist in NRL3, whereas the next month the network could exist in NRL 2, based on events in the network. It is interesting to see whether the NRL is capable of indicating this, and what the user of the NRL thinks of the tool in these cases. This recommendation connects to the recommendation made in the previous paragraph, but specifically holds for the NRL –indicator.

In the discussion of the theoretical contribution of this thesis, a remark was made on applying the NRL on a larger scale. This research looks at the NRL on a low level scale, but the energy transition, and socio -technical systems exist on a worldwide scale. In a follow up research, a scale to asses the progress of the energy transition of a national scale could be drafted. The NRL -scale could on this higher level be used to make a snapshot of the progress of the energy transition. Based on this snapshot, future policy could be determined. As an example; the Transition Pathways propose different situations through which a transition in a system could take place on a high level (Geels, 2007; Verbong, 2010). In these publications, however, no numerical indicator exists to indicate the progress of the transition pathway. Combining the idea of the NRL -scale with the Transition Pathways could provide a method to indicate the progress of a transition, and provide a way to communicate the progress of the transition. This would take the NRL -scale from the low level socio -technical scope to the high level scope of a complete system.

8.3 Recommendations for Tata Steel

The NRL –indicator is drafted based on cases with socio -technical characteristics of Tata Steel IJmuiden. Some of the cases were running smoothly, while others were hindered in their development. The NRL –indicator could be used in these, and future projects to structure the development. The NRL –indicator could be used as an internal checklist for projects with external actors, to internally keep track of the development. The user of the NRL –indicator could reason what criteria are present in the collaboration, but also how absent criteria should be included. The methodology could be used as a ‘thermometer’ in combination with a ‘diagnosis’ in the projects concerned.

The true value of the NRL -indicator, however, could come forward if the methodology is applied in consultation with the other actors in the projects. If from the beginning of the project, the NRL –indicator is used during meetings to create a shared idea of the development, the value of the methodology could be expressed. The methodology could indicate where the development lags behind, and which actor has to do something about this. Furthermore, the indicator could show what the next steps in the project are based on the criteria and the actors could fill in the criteria based on project specific characteristics. To summarize the NRL –indicator could facilitate the collaboration in a network of different actors working together on a socio –technological development. The NRL –indicator does this by facilitating communication, structuring the collaboration, and by inviting the actors to engage in discussions on how to stimulate the projects further. Not only projects with external actors could be facilitated by the NRL –indicator, also in internal projects with multiple internal actors the methodology could be applied. The criteria should be changed based on the need in the project.

8.4 Personal Reflection

I enjoyed conducting the interviews, and learned a lot on the different cases, and on the soft factors of conducting a project in a collaboration. The interviews provided numerical data, but also many subjective data based on expert opinions. The analysis of the data was expected to give problems, which turned out to be the case. The large amount of numerical values, experts opinions, and typed out interviews, gave troubles in structuring the results, and finding a way to change this data into an applicable tool. The final 4 –step result analysis method that was drafted provided the way out.

Without jumping to conclusions, or missing important opinions I could structure the data and create the NRL –indicator. This was the biggest achievement in my opinion, since it showed a clear structure and line of reasoning. Creating structure and a clear line of reasoning is immediately the biggest challenge I had in conducting this research. The question I had to ask myself was: ‘ How to transfer my thoughts in a clear way, and without too many words?’. This is something I have improved over the course of this thesis with the help of Rob. He gave me a much clearer idea of how to structure work, and what are the important parts of a research, as compared to my previous ideas. I think I finally understand how to structure my reasoning, and the output. Also expressing ideas in as little words possible was a challenge , because I simply wanted to include too much in the thesis. In the end the main thesis was cut down hugely, by trying to write in a structured way, only stating the needed information. I can sometimes have the idea that things have to be overexplained.

The overall remark that could be made based on my learnings is: ‘ Less is more, but…’. – Julius Groenendaal

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Appendix A

Scientific Article

Based on the outcomes of this thesis a scientific article is drafted with the title: The Readiness Assessment of the social dimension of a socio -technical system on a level scale: the NRL - indicator. This paper is presented at the back of this thesis. After Appendix I the scientific article will follow.

Appendix B

The TRL

B.1 The Technology Readiness Level (TRL)

The TRL scale was first proposed by a NASA researcher (Stan Stain) in 1974 to indicate the level of development of new technologies. The scale, however, did not have real definitions, and levels of development until 1989. The TRL was officially adopted by NASA in 1990, and had 9 levels of development (Banked, 2017). The TRL was used to help the management make decisions on the development of a new technology, by making the assessment of the development process easier. The management could easily indicate in which level of development a new technology was, and determine its 'stop-go decisions', or further investments in the technology. Besides this, the NRL was a way to facilitate/unify the communication about the maturity of new technologies (Mankins, 1995, 2009). The understanding of TRL 5, for instance, was the same organisation wide, providing easier communication among different departments, and levels of management. After NASA, different organisations drafted their own TRL based on the original scale, but adapted to their own technological field. For example, the U.S. DoD, the ESA, the European Commission, and the Oil & Gas Industry (European Commission, 2015; Graerringer, Garcia, Sivily, Schenk, & Van Syckle, 2002)**.** This shows the strength of the concept, but also the adaptability of the structure, making it applicable in multiple sectors, and markets.

B.2 The TRL explained

The TRL scale consists of 9 levels of development (TRL1-TRL9). In which an indication in TRL 1 means that the basic principles of a technology are observed, and TRL 9 shows that the actual system is proven through successful mission operations.

The nine levels of the original scale TRL developed by NASA:

TRL 1: Basic principles observed and reported
TRL 2: Technology concept and/or application formulated
TRL 3: Analytical and experimental critical function and/or characteristics proof of concept
TRL 4: Component and/or breadboard validation in laboratory environment
TRL 5: Component and/or breadboard validation in relevant environment
TRL 6: System/subsystem model or prototype demonstration in a relevant environment
TRL 7: System prototype demonstration in an operational environment
TRL 8: Actual system completed and qualified through test and demonstration
TRL 9: Actual system proven through successful mission operations

The 9 levels follow the technology from a stage in which the first tests are done to find out properties of materials (TRL 1) to the stage of a 'flight proven' system (Mankins, 1995). In the first two levels, the potential of the technology is speculative, and no real research has been done, but there is an idea on the potential of the technology (TRL 1-TRL2). In TRL 3, the technology is in the R&D phase. The technology is tested both by introducing it in its context, and by actual laboratory based validation. The following two levels (TRL 4 – TRL5) are used to test the technology in the laboratory, and relevant environment. This shows a first indication of the importance of the context, or environment on a technology. A step is taken towards TRL 6, since the system/subsystem model of the technology should be tested in its 'relevant environment'. From this level on the development is more dependent on support by the management, than on actual R&D, since multiple promising technologies are expected to be present in NRL 6. It is the management decisions that should decide on the further development of a technology. In TRL 7, the first prototype is tested in its environment, representing the actual outcome of the technological development. The final two levels of development (TRL 8 – TRL 9) show a completed system, and a tested technology. To these 9 levels of development an economic indication of the made costs in each TRL level can be attached, showing the combination of technology & economy. The investments in the development are expected to grow in each stage of the TRL(Mankins, 1995).

Appendix C

Cases of Tata Steel IJmuiden

C.1 The Cases of Tata Steel IJmuiden

In this Appendix the cases of projects on renewable energy development, and waste heat usage at the Tata Steel site, and its surroundings are discussed. The cases are chosen in consultation with Gerard Jägers, project manager Energy Efficiency of the TSIJ site. The cases are discussed based on data from Tata Steel documents, external sources on the project, and preliminary results of the interviews related to the project of concern. The goal of the case study is to obtain an insight into the background of the cases, and the current status of the projects. The description of the cases is structured by using the framework for TIS analysis, as proposed by Hekkert. At first background information on the Tata Steel site will be provided, explaining the willingness to participate in renewable energy projects. The introduction is followed by the explanation of the structure of Hekkert, which is used to structure the description of the discussed cases. Finally, an introduction is given into the cases of renewable energy, and waste heat usage, in combination with

Background Renewable Energy & Waste Heat at the TSIJ –site

Tata Steel IJmuiden (TSIJ) is the only integrated steel plant in the Netherlands. The site of TSIJ is located just north of the Noorzeekanaal, and is located in the municipalities of Velsen, Beverwijk, and Heemskerk. The total area spans around 750 hectares, an equivalent of 1500 football fields, therefore the largest industrial plant of the Netherlands. A map of Tata Steel IJmuiden is included in Appendix C.5. Due to the sheer size of the plant; international, national, regional, and local policy apply to the TSIJ –site. For example, TSIJ is part of the ETS system for CO2 trade, is part of the negotiations table of industry in the new Energy Agreement of the Dutch government, but is also part of local policy to improve the quality of life of local residents.

Tata Steel is subject to the changes that the energy transition entails, in terms of reducing energy usage, and CO2 emissions. Tata Steel is actively involved in this transition by efforts to reduce the CO2 emissions of their production processes, as the main focus of their contribution to the energy transition. Besides, the production processes, Tata Steel wants to contribute by striving for a more sustainable society, contributing to the renewable energy targets of the government for 2020 (and beyond), and improving the local environment. Next to the own incentives, Tata Steel is bounded by governmental regulations on energy and emission targets. As an example, Tata Steel is part of the Meerjarenafspraak Energy-efficiency ETS-ondernemingen. In this agreement a 1% energy reduction in production processes is strived for on yearly bases. It is these incentives that make Tata Steel look for options, beyond the savings on energy and CO2 in the production processes. Although the company has a clear priority in investing in steel production, since this is a core business, different renewable energy, and waste heat projects are pursued in collaboration with other actors.

The following projects are considered:

- The development of Wind Park Ferrum at the TSIJ –site.
- The installation at the roofs of production facilities at the TSIJ –site.
- The development of a DH –network in the IJmond region.

The projects require collaboration with other companies, governmental authorities on different levels, research institutes, local interests groups, and action committees, due to multiple reasons. At first, since the expertise on renewable energy projects and district heating networks is missing. Tata Steel is a steel production company, and not an energy company. As a second reason, the investment budget for the renewable energy projects is low, due to the focus on the core business of steel making. Other actors are actively pursued to engage in collaborations, to execute to projects. Finally, the projects have an impact on the environment, not only on the TSIJ –site, but also outside of the gate. Rules & Regulations, different interests, environmental laws, and policy on different scale, other companies, other actors, are all influencing the development of the projects.

In order to show the connection of the TSIJ renewable energy projects, to different actors, and different levels of policy. A map with the different scales of policy is provided in Appendix C.6.

The government collaborates with Tata Steel on the energy reduction targets of the company. On a lower provincial scale, the Province of Noord – Holland provides advises on -and monitors the development of renewable energy projects in the province. The Province has targets for the amount of wind turbine capacity on land. Further, the province is the authorized supervision in the development of a DH –network, and the authority giving out permits for the development of wind parks. In the case of the wind park at the TSIJ –site, the permit procedure was facilitated by the OD NZKG, an authority giving out environmental permits for the area of the Noordzeekanaal, on behalf of the Province. This made another governmental organization part of the project.

Another level, the MRA, although the level has no authority, was present in the DH –network development. The MRA ‘WarmteKoude’ project on the development of a regional heat infrastructure appointed a regisseur to develop the ‘Grand Design’ of district heating networks, connecting 32 organizations including Tata Steel. In this Grand Design, multiple smaller DH –network collaborations were set up, including one in the IJmond region, facilitated by the OD IJmond. The OD IJmond is an authority representing, among others, the three municipalities in which the TSIJ –site is located. The authority gives out permits, and monitors environmental laws. This makes another authority part of a project. Finally, the energy cooperatie Wijk aan Zee represents the common interest of the inhabitants of WaZ, who are influenced by the new to build Wind Park at the TSIJ –site.

The map and the description show the amount of governmental organizations present in the development of the renewable energy, district heating projects at the TSIJ –site. The other companies, and internal actors of Tata Steel, are not even mentioned, showing the large number of actors involved, and the need to collaborate in these projects. Collaboration in these networks of actors for renewable energy development, and waste heat re-usage forms an input for the creation of the NRL, because many driving, and hindering factors are encountered.

In the following description of the cases, the different actors and their roles in the projects are introduced. Accompanied by a description of the technological, and economic factors influencing the projects. The perspective of Tata Steel is used to describe the case, meaning that the potential influence of institutions, and economic factors described from a Tata Steel perspective.

Framework Used to Study Cases

Hekkerts' Functions of Innovation Systems

To study the three cases, a framework to analyse Technological Innovation Systems (TIS) is used. This framework is proposed by Hekkert in his works on Innovation Systems. The framework consists of five steps of analysis that should clarify the system studied in terms of; actors involved, institutions influencing the project, concerned technology, phase of development, failures in the system, and functions that are supported by the system (Hekkert, Marko ; Heimeriks, Gaston; Harmsen, 2011; Hekkert et al., 2007) Although TIS is set -up to incubate innovative technologies, the framework, after some adaptations, is applicable to structure the description of the cases. It gives a clear overview of a project in different steps, providing a general overview of the studied project. Hekkert presents his framework in the following steps:

Step 1	Step 2	Step 3	Step 4	Step 5
Structure	Phase of Development	Functions of Systems	System Failures	Policy Instruments

Figure C.1.1 – The five steps of analysis of Hekkert to describe a TIS. This framework is changed slightly to fit the description of the Tata Steel cases.

The framework as proposed by Hekkert is slightly adapted to fit the description of the cases, by implementing two changes. Step 3- Functions of Systems is left out of the analysis, since Hekkerts' functions of systems step is related to the key activities in an innovation system. The current research looks at the implementation of technology, instead of innovation. These functions deviate too much from the activities of implementation, and the step is left out of the analysis. Further, Step 5 (Policy Instruments) is changed into Key Learnings, since the analysis of the cases aims to find out what went well, and what did not went well during the projects. These key learnings come forward from the interviews, and represent the specific remarks made on the successes, and problems during the projects. Besides this change, the notification must be made that when not enough information is present on a step of analysis, the step is left open.

The adjusted framework

The cases are studied with the adjusted framework of Hekkert. The cases are introduced by a short introduction, after which four-steps of the framework are presented. Step 3 (Functions of Systems), is left out, since this will not be used. The Step 3 is replaced by Systems Failures. The adjusted framework of Hekkert is presented next.

Step 1 – Structure

The structure part of the projects is based on the description of four components of the projects, and an added fifth component, the economic factors:

1) **The actors:** the actors involved in the case of interest are mentioned, and their role is described.
2) **The institutions:** the institutions, both internal, and external, influencing the development of the network, are presented.
3) **The network:** the network of the project is presented in an organogram, presenting a schematic overview of the relations between the actors in the network.
4) **Technological Factors:** the technological characteristics of the projects are presented. A TRL is assigned to the technology in question. An explanation of the TRL is provided in paragraph 5.1.
5) **Economic Factors:** the economic factors, and the investments in he projects are presented.

Step 2 – Phase of Development

The phase of development of the project indicates which steps have been taken, without assigning a specific level of development to the project. The current status of the project is presented by indicating the steps that have already been taken by TATA Steel, and other actors to contribute to the final project.

Step 3 – Systems Failures

In the fourth step actual barriers that hindered the development of the project are presented. This is limited to the barriers that were found in the case documents. Where in the project did problems occur? What caused the project to work well at some points? These questions will be central in the expert interviews, but the cases are studied for these factors as well to create an insight into the difficulties of the projects.

Step 4 – Key Learnings

In the description of the cases, the key learnings from the projects are based on remarks made on the specific cases by interviewees. The Key Learnings provide an overview of what went well, and what went wrong during the cases, to be used for future collaboration. The cases are described based on internal sources of the Tata Steel server, therefore often no reference to sources is present.

C.2 The Development of Wind Park Ferrum

Introduction into Wind Park Ferrum

The IJmond region was indicated by the province of Noord-Holland as a potential location for the realisation of wind turbines, in the policy for 'Wind op Land' (N-H, 2018)**.** Already three wind turbines are present at the Reyndersweg, right outside of the TSIJ –site, and the number could be expanded. In the policy, aimed at expanding the capacity of on –shore wind in the province of Noord – Holland, the province and the national government agreed upon the realisation of 685.5 MW capacity of wind energy. This 685.5 MW was aimed to be in operation in 2020 (N-H, 2015). The request by the province, caused an initial trigger to look for the potential of wind turbines at the TSIJ site.

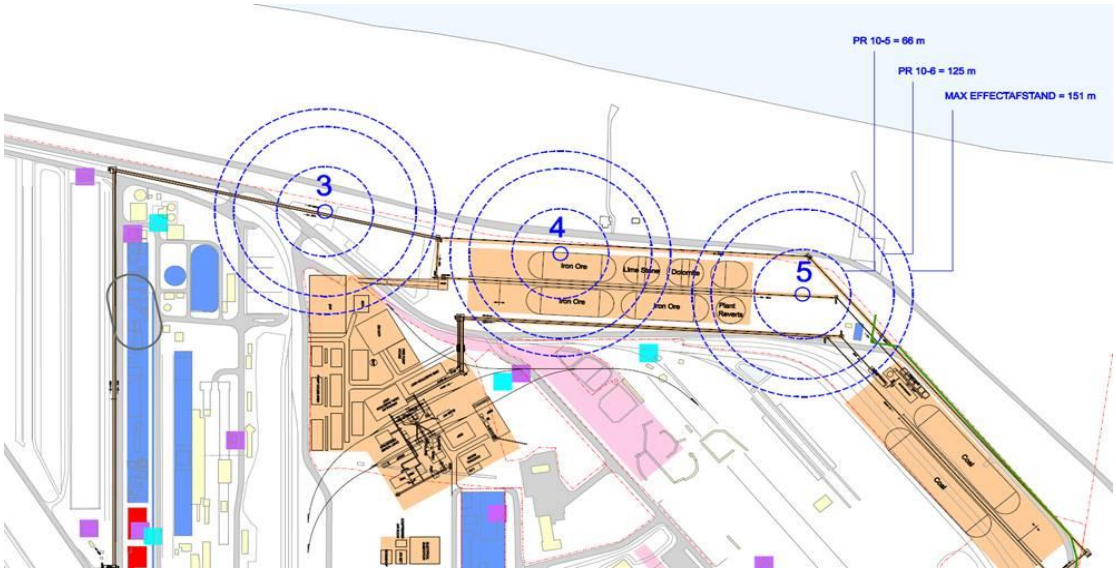

Figure C.2.1 – The three wind turbines of Wind Park Ferrum, located at the north - western border of the TSIJ – site. The small circles represented by 3, 4, 5, are the turbines, the circles surrounding the turbines are the critical distances of the wind turbines. In Appendix H a map of the total TSIJ –site is presented.

A total of 5 scenarios for placing a total of 8 wind turbines at the TSIJ –site were developed. These were sent to the province of Noord-Holland for the permit application. Only one application was processed in the end, due regulatory restrictions of the provincial decree on 'Wind op Land'.

The approval of this one scenario lead to the plans for Wind Park Ferrum. In this scenario, 3 new wind turbines, with a capacity of 2-3MW, are placed in the extension of the currently existing 3 at the Reyndersweg (Wind Park Ferrum, 2018). The request for an environmental permit was submitted in May 2016, with extension in June, and October. On the 14th of March 2017 the final green light was given by the province for the construction of the wind park.

Tata Steel looked for collaboration with different public, and private parties to execute the project on Wind Park Ferrum, since Tata Steel had no experience with building a wind park, and all the related procedures. The company, therefore, aimed to create of network of actors to develop Wind Park Ferrum at the Tata Steel site. To start the project, some pre –determined requirements were set up, functioning as a starting point for further network creation:

- The potential partner would engineer, manufacture, and install a (x) number of wind turbines.
- The project should not influence the steel making practices of Tata Steel
- The investment in the wind turbines is taken on by the partner
- The TSIJ electricity grid could be used to transport electricity to the grid. Tata Steel will buy the generated electricity at APX market prices
- Small local energy cooperation's are looked for in the project development, to include the surroundings in the project

Step 1 – Structure

Actors

The first component of the structure part of the analysis is the involved actors. The actors that were present in the project are mentioned, and a short description of their role in the project is provided

Tata Steel: The company acts as an initiator of the project. In the starting phase of the project, the company initiated the collaboration for the wind park development by finding partners for cooperation. The company appointed a project manager, and technical project manager to the project, as the persons working together with other actors. Besides this, Tata Steel provides the land needed for the wind turbines, through a lease contract, however, the company will not invest in the wind park development. Tata Steel will act as the author of the permit, since the wind turbines will be placed on the site of Tata Steel. The company is presented as a single actor in the network, but many internal stakeholders were involved in the project too. These are outside of the scope, due to the external collaboration focus of this thesis.

Infinergy: Infinergy is an experienced developer of renewable energy projects around the globe. The company was selected by Tata Steel to execute the construction of the wind park, and provide a part of the funding. Infinergy took place in the steering group of the project, together with Tata Steel. Further, the company is partly owner of the wind turbines. Infinergy contracted Green Solver for the financial evaluation, engineering, operation and maintenance of the project.

RoyalHaskoningDHV: RoyalHaskoningDHV is specialized in engineering, design, and project management consultancy. The company has unrivalled knowledge of the TSIJ- site due to earlier projects, and long-term collaboration. The company was chosen by Infinergy to effectuate the feasibility of the project, and to provide the studies needed for the permit request. The company has conducted all the studies on the environmental effects, noise pollution, safety, shadow, during the project.

Windcollectief Noord-Holland: Windcollectief Noord-Holland is a collaboration of an energy cooperation, and multiple private wind turbine operators. The collaboration owns multiple wind turbines scattered around Noord – Holland. Together with Infinergy the collective will provide the funding of the wind turbines, and is the owner of the wind park. Since the Windcollectief is owner of multiple wind turbines, the collaboration is able to supply wind turbines for the 2 for 1 rules of the province, which is further explained in the **external institutions** part.

Wind Park Ferrum B.V.: Wind Park Ferrum B.V is a joint-venture between Infinergy, and Windcollectief Noord-Holland, both investing in the wind park. The joint venture was created to comply with the 2 for 1 rule, posed by the province of Noord-Holland.

Liander: Liander is a DSO in the IJmond region, and will be responsible for the connection of the wind park to the electricity grid. As a first initiative, the idea of transporting the electricity through the grid of TSIJ was suggested. After initial consulting this idea was feasible, but juridical constraints caused the need for a new connection to the grid, connected by Liander.

Province of Noord – Holland: The province of Noord-Holland has drafted the rules & regulations for the development of new wind parks in the province. Besides this, the province was the competent authority, they were the authority granting permits for the development of the wind park.

OD NZKG: The OD NZKG is responsible for the issuing of environmental permits in the area surrounding the Noordzeekanaal. In the Wind Park Ferrum case the request for the permit was handled by the OD NZKG. The final approval was given by the Province.

Milieucooperatie Wijk aan Zee: The cooperation represents the common interests of the inhabitants of Wijk aan Zee, and aims at a more sustainable society. The cooperation became part of the network, since the wind park will be build close to the village, causing nuisance for the population, but also the possibility of participation. The Milieucooperatie Wijk aan Zee has looked together with the other actors at ways in which the inhabitants could participate in the wind park, and was therefore engage in the negotiations on the wind park. As a result a 'region fonds' was founded, in which some of the profit gained by the wind park will be gathered. From this money new projects improving the sustainability of the environment are financed.

Dorpsraad Wijk aan Zee: The dorpsraad Wijk aan Zee represented the common interest of the inhabitants of Wijk aan Zee in the project. They were included early on in the project to provide feedback on the plans of the wind park.

Institutions

The second component of the structure part is the institutions influencing the development. These institutions can be divided into *external* institutions, posed by the government, and the *internal* institutions, the rules that have been drawn up within the network, or Tata Steel. Both the external, and internal institutions are discussed.

External Institutions

Provincial Decree

The Province of Noord-Holland present specific rules, and regulations for the development of new wind parks in their *Herstructurering wind op land* (N-H, 2018). The decree that supported the development of Wind op Land. The decree presented four rules that had to be met:

(1) 6 aligned wind turbines: the wind turbines had to be placed in a line of 6. This line could be straight, curved, but also broken to a certain extent, depending on the situation of the project. It posed, however, the restriction that wind turbines could not be placed individually, or in groups of 2, but had to be in a line of 6 turbines. In combination with the already existing turbines at the Reyndersweg, the 3 new turbines of Wind Park Ferrum formed a line of 6.
(2) 600 m distance from housing: the minimum distance between the wind turbines, and housing needed to be 600 m.
(3) 2 for 1 rule old turbines: 2 old, individual turbines, somewhere in the province, had to be replaced by 1 turbine in a line of 6, to comply with the new rules. This causes a decrease in the total number of wind turbines in the province, but a higher total power capacity, due to the higher capacity of the new wind turbines. This caused Infinergy to engage in Wind Park Ferrum B.V. with Windcooperatie Noord –Holland, since they had individual wind turbines available throughout the province to comply with the rule.
(4) Similar Appearance: New wind turbines were required to have a similar appearance to the wind turbines where they were place in the extension of.

Especially the 6 aligned turbines, and the similar appearance, caused problems in the project. Of the original scenarios (for a total of 8 wind turbines), multiple scenarios existed in which the turbines were not aligned in a line of 6. These scenarios were rejected because of the decree, resulting in only one approved scenario. The wind turbines in this scenario needed to have a similar appearance to the three turbines at the Reyndersweg. This resulted for the choice of lower capacity wind turbines (2 MW instead of 3MW), because the 3MW turbines with a similar appearance were no longer in production.

Permit Procedure

Besides these preliminary restrictions, the procedure for the permit of the wind park was strict. This influenced the development of the wind park. The procedure consisted of two phases:

Phase 1: Research on the environmental, and planning aspects of the project. Different studies had to be conducted on the: spatial foundation, effects on the nature, noise pollution, drop shadow, air quality, and safety of the project. The outcomes of the studies had to be submitted to the OD NZKG.

Phase 2: Request for the actual building permit of the wind park. Civil engineering aspects of the project are tested.

Internal Institutions

Preliminary requirements for the project were present in the list presented in the introduction. Besides this, different requirements for the partner selection were drawn up before the project. The requirements consisted of three parts: (1) Preliminary list of partners, (2) RFI 1, (3) RFI 2.

A preliminary list of contractors for the project was drafted by Tata Steel to make the selection process easier. The RFI 1 presented guidelines for the selection of the constructor of the wind park, such as; experience with TSIJ, local authorities, financial robustness, or green image. Adding to these guidelines was the notion of a preference for a qualitative supplier selection, rather than a tender procedure. The second part, or RFI 2 presented more precise guidelines on the characteristics of the project.

Network

The network of actors working on the wind park project existed of many private, and governmental actors. Tata Steel only contracted one actor to engineer, manufacture, and install the wind turbines, which was Infinergy. The other parties were later included in the network. The different actors in the network are represented by the different spheres (nodes), and the relations between the actors by the lines (edges). The boundaries surrounding the network are formed by the institutions of influence on the network; the Provincial decree for 'Wind on Land', and the permit procedure of the OD NZKG. The role of the different actors in the network is presented in the paragraph Actors part of the Structure paragraph. The connection between the different actors is stated along the different edges.

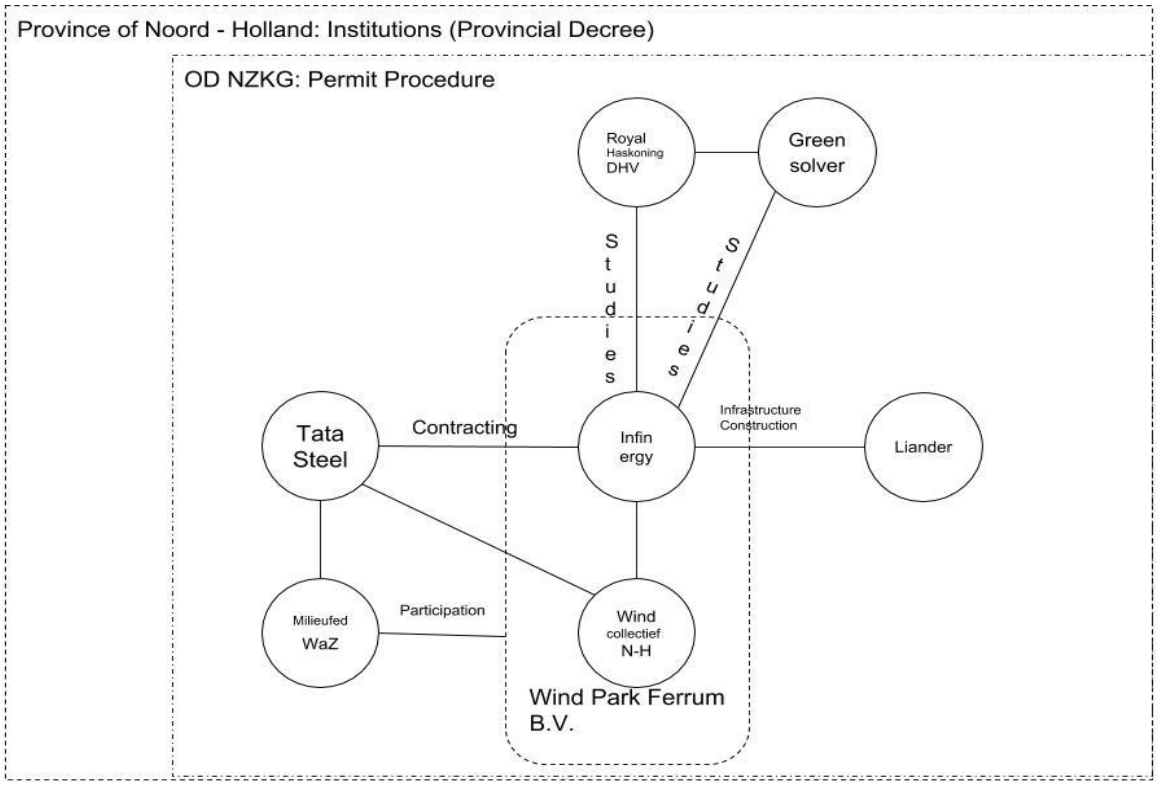

Figure C.2.2 – The network of actors for the development of Wind Park Ferrum. The dotted rectangle represents Wind Park Ferrum B.V. The boundaries of the network are formed by the institutions influencing the network in the form of the permit procedure, and the provincial decree.

Technological Factors

TRL

The construction of a wind turbine, and the introduction of wind energy into the grid are considered proven technologies, as was responded by interview 3, 5 &8. This places the technology in **TRL** 9. The project is on the implementation of a technology, and not about further development, and testing the technology. One could argue, however, on whether the technology has been proven in its current environment, since each project in wind park development is different. The safety regulations of Tata Steel provide strict requirements for safety issues, for instance. This is not indicated in the TRL scale. The scale provides the possibility to test a new technology in its environment, but testing a wind park is not possible. The development of the wind park has therefore been assessed based on the feasibility studies by RoyalHaskoningDHV, providing the insight that the project was implementable in its current environment.

Potential

Wind Park Ferrum consists of three wind turbines, each with a capacity of 2 MW. The potential of the wind park is expressed in annual numbers (Wind Park Ferrum, 2018). The initial wind turbines had a capacity of 3MW, but restrictions in the decree on wind turbines caused the choice for 2MW wind turbines.

Factor	Value
Capacity	2 MW ($2\times 10^3 kWh$)
Annual Full Load Hours	2.190 hours (on average)[10]
Number of Turbines	3

Figure C.2.3 – The annual numbers of Wind Park Ferrum

The following formula can be used to calculation the generation of the wind turbines:
$Annual\ Yield = Capacity\ \times Annual\ Full\ Load\ Hours\ \times Number\ of\ Turbines$

This leads to the following outcome:
$Annual\ Yield = 2\ \times 2.190 \times 3 = 1.3 \times 10^4\ MWh$

This amount is equal to approximately 1% of the total electricity usage of TSIJ, which puts the whole project in perspective[11]. The reason to execute the project is the contribution to society, the PR value, and to pursue all possible ways of contributing to the energy transition. Only a tiny percentage of the total electricity use of the TSIJ –site will be generated by the wind turbines.

Economic factors

Tata Steel does not invest in the wind park, and will only provide the land to build it. This means that an external investor, and developer had to be found in the form of Infinergy. Besides an investor in the wind park, two different business models concerning the Wind Park were proposed to sell the electricity generated to Tata Steel. The first business model was chosen.

[10] The Annual Full Load hours are based on an average (https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/duurzame-energie-opwekken/techniek/opbrengst)

[11] This percentage is based on an annual electricity usage of the TSIJ –site of $2{,}1 \times 10^6\ MWh$. $\frac{3\times(4{,}4\times 10^6\ kWh)}{2{,}1\times 10^6\ MWh} \sim 0.01$

Model 1 – Power to Tata Steel

In the case of Power to Tata Steel, the generated electricity is sold back to Tata Steel at market prices. This would force Tata Steel to buy 'green' electricity at a higher price than their current electricity price (based on electricity generation from natural gas), which means higher costs of electricity. The benefits of this model would be the issue of Green Certificates to Tata Steel, due to the renewable energy generation, and consumption. Besides this, the land used for the wind park is leased by the owner of the wind park (Wind Park Ferrum B.V.), resulting in an annual cash flow for Tata Steel. To wrap up, in this case Tata Steel will buy the electricity generated by the turbines, and will receive green certificates, and a cash flow out of the land lease.

Model 2 – Power to neighbours of choice and/or TSIJ employees

In the second case, the electricity generated is sold to predetermined neighbours (of the TSIJ site), and to employees willing to participate and buy green electricity. Giving the opportunity to companies, and employees to access green electricity. Tata Steel would only make the land available for construction, and receives the rent for this. The owner of the wind park would receive the green certificates. All investment, and all revenue from selling electricity to the grid is generated by the owner of the wind park.

Step 2 – Phase of Development

In step 2 the phase of development of the project is explained, based on the current status of the project, and the steps that were taken during the development of the network. If a project plan was used by Tata Steel, the project plan is presented to show how the project was structured.

In this particular project, Tata Steel used a stepwise, project managerial structure. The structure consisted of 4 Steps and different tasks that had to be conducted before the end of each step. The stepwise structure shows a chronological order, and a clear overview of the tasks.

Step 1: Business Case & RFI	Step 2: Pre –engineering & Risk Analysis	Step 3: Engineering	Step 4: Commission
RFI part 1	Partner selection	Location confirmation	Financial Close by partner
Map with critical buildings		LOI	
Business Case checked			
RFI part 2			

Figure C.2.4 – Schematic overview of the project plan for the Wind Park Ferrum case, as drawn up by Tata Steel.

Tata Steel started the project by looking for potential partners to build the Wind Park. Five potential partners were invited to draft a proposal, and present a business case. The RFI 1 gave the requirements for each of the invited parties. The RFI 1 mostly contained qualitative aspects, aiming at a fruitful, and smooth collaboration. A first **choice of partners** was therefore made based on **qualitative criteria.** The next step was to check the different business models, meaning an **economic assessment** of the plans to operate in a network of actors. Finally, an analysis of the companies' plans for specific key points in the project was done. The key points were presented in the RFI 2, which was the end of step 1.

By finishing step 1, the partner selection for the network started in step 2. After choosing the first partner for the network (Infinergy), a **risk analysis** was conducted. This analysis was conducted by a new member of the network (RoyalHaskoningDHV), contracted by Infinergy. Leading to results of the different tests that had to be done based on the **provincial institutions**.

This made the Province of Noord – Holland, and the OD NZKG actors. They were involved as licensing authority, facilitating the permit procedure. After the introduction of the governmental authorities, the Windcollectief Noord-Holland became part of the network. The Windcollectief was contracted by Invenergy, creating the **Joint Venture** of Wind Park Ferrum**,** which was out of the scope of Tata Steel. Tata Steel started the network, and provided the land for the construction, but would not be part in financing the project.

The land is owned by Tata Steel, and the permits are requested by Tata Steel, so **sufficient stakeholder management** is needed, both on –site and in the surroundings. Before the **location confirmation** was requested, all internal stakeholders of the TSIJ-plant were informed.

Also a walk –in evening for local residents, interested in, or concerned about the project was organised, which included the local residents in the network. The residents of Wijk aan Zee are united in the Mileucooperatie Wijk aan Zee, who participated in the negotiations on the wind park, resulting in the founding of a 'regio fonds'.

A **LOI** was drafted to secure the collaboration for the engineering of the project at the beginning of Step 3 in the process. The development of the Ferrum wind park is currently in step 4. The Letter of Intent between Tata Steel and Infinergy was signed, and all the construction permits were provided by the Province in July 2017. SDE+ subsidy was granted in October 2017. Momentarily fist ground research on the firmness of the soil, providing data on the basement of the turbines are executed. Besides the ground research, the route of the cable connecting the wind park to the grid is ready for approval. The aim is to start the ground work on foundation by the end of 2018. The wind park is aimed to be up and running in October 2019

Step 3 – System Failures

In step 3 the system failures are discussed based on findings in documents concerning the project. The words in **bold** are specific facilitators, and barriers, found in these documents. The specific factors that influenced the system negatively provide an insight into where the project was hindered, and what caused failures in the development of the network.

The overall feedback on the project was good. **Communication, and collaboration** during the project was good between the actors in the network. The **experience of the partners**, and **professional support** contributed to this. There was **willingness by all parties** to tackle the problem, and the Province of Noord-Holland provided **pressure, and steering.** The pressure was provided in terms of deadlines, and strict rules for constructing the wind park.

On the contrary, negative aspects were experienced during the project. The **authorisation** of the Tata Steel board was too complex, and **legal support took too long**, since the project was not approached with the normal project managerial approach. Also **internal communication** about changes in the project was not updated during the project, leading to situations in which certain actors were not aware of the stage of development. The fact that the project was not executed with the **normal procedure** for projects, was considered an important factor for project difficulties. Also **last –minute demands** of provincial, and regional organisations caused pressure to the project.

Facilitators	Barriers
Good Communication	Long time before legal support
Experience of the Partners	Last –minute demands by external institutions
Pressure, and guiding by external institutions	Project not approached as a normal project
Willingness by all parties	

Figure C.2.5– Overview of the project specific Facilitators and Barriers mentioned during the interviews.

Step 4 – Lessons Learned

The lessons learned from the project come forward from the interviews:

- **The partner selection** for the project was well structured, and based on qualitative criteria primarily. In the RFI 1 & RFI 2 these qualitative criteria were included. After these criteria the potential business cases were considered. This method resulted in a good partner selection, which was seen as contributing to the project.
- **All actors potentially involved** in the project were included **from the beginning** of the project. The actors were divided in Expecting Actors & Demanding Actors. Of which the expecting actors had to be included based on their expectancy, and the demanding based on the collaboration that was started with them. Including all actors from the beginning created the support for the project.
- In the project the different experts from Tata Steel side, and the other actors were brought together. The noise expert talked with the noise expert, the project leader with the project leader. These encounters off course happen during the project, but bringing the different actors actively together created a good understanding, and a **shared idea** of the project.
- **Clear company Strategy & Goals** for renewable energy projects would have made the project easier. The absence of a strategy caused the fact that decisions were doubted by internal actors. A clear strategy would have taken away this doubt. Many different internal actors had an opinion, and their own expertise on the project. The underlying factor here is the fact that the renewable energy projects are not steel related, and are in competition with future steel related projects. Clear strategy is needed to convince actors of the importance of the renewable energy projects.

C.3 Developing Solar Power on site at TSIJ

Introduction into the TSIJ Solar Panel project

In 2012 the first solar panels on the TSIJ -site were constructed in a collaboration with Eneco on top of the Dudok Huis[12]. These solar panels, a total of 500, have a capacity of only 0.1MW. This was only a very small part of the total potential for solar energy at the TSIJ – roofs. In order to utilize the potential, contribute to the energy transition, and improve the green image of Tata Steel, the motivation was present to start a project on placing solar panels on top of the roofs op production facilities at the TSIJ –site. Raedthuys (part of Pure Energie) was the actor that approached Tata Steel to start the project. The company wanted to request an initial SDE+ subsidy for 3 MW of solar panels. An additional subsidy for 18 MW of solar panels was requested, resulting in a total of 22MW of solar energy subsidy. The 22 MW of solar panels had to be constructed on top of the roofs of the different production facilities of the TSIJ –site. Tata Steel approved, on the following three conditions.

- There is no economic incentive for Tata Steel, and no investment in the solar panels is done from Tata Steel side.
- There needs to be a possibility to switch off the solar panels when this is needed. The steel production process should not be hindered by the solar panels. If the production processes ask for the solar panels to be switched off, this should be possible.
- The electricity, generated by the solar panels, should not be more expensive than the electricity is currently.

Step 1 – Structure

Actors

The first component of the structure part of the analysis is the involved actors. The actors that were present in the project are mentioned, and a short description of their role in the project is provided

Tata Steel: Tata Steel was not the initiator of the project, since Raedthuys approached Tata Steel for a collaboration. Tata Steel is the owner the roofs needed for the construction. The investment in the solar panels is not done by Tata Steel. The value of the project lies in contributing to the energy transition, and the PR –value of the largest rooftop solar project of the Netherlands. The solar panels are invested in by an external party (Raedthuys), who will sell the generated electricity to Tata Steel at APX market prices. After a period of 15 years, the solar panels will become property of Tata Steel at zero costs. Tata Steel is presented as an individual actor, but has many internal actors involved in the project. An example of these are the production facility managers, since they have to give permission for the construction of solar panels on the rooftops. These internal actors are not mentioned in the cases, due to the external scope of the research.

[12] Dudok Huis is the main building at the entrance of the TSIJ –site.

Raedthuys: Raedthuys is an experienced company in projects concerning the development of wind and solar energy. It facilitates the processes, arranges the permit procedures, but also invests in renewable energy projects. The company was selected for the engineering, investing, installing, and maintenance of the solar panels based on its experience. Raedthuys becomes the owner of the solar panels for a period of 15 years, and sells the generated electricity back directly to Tata Steel. Raedthuys requested the SDE + subsidy for the solar panels, and received the subsidy.

Tata Steel Solar Power: Tata Steel Solar Power is part of Tata, and will be the supplier of solar panels for the project. The company has experience with installing over 1000 MW of solar panels in India. The party is included in the project by TSIJ, based on the idea of the internally produced solar panels.

Institutions

External Institutions

Due to the installation of the solar panels on the roofs of the TSIJ –site, there are no external institutions influencing the project. There are no environmental permits needed, or governmental decrees influencing the development, solely the safety rules & regulations. The only external institution that influences the network is the availability of the SDE+ subsidy for renewable energy generation. This SDE+ subsidy starts at a specific day, and lasts for 15 years from that day. The delay in the project caused the period of the SDE+ subsidy to start already, without the solar panels generating electricity. This causes a shorter subsidy period.

Internal Institutions

Within the network, different institutions, or company owned policies are present. An example of this is the fact that Tata Steel does not invest in the solar energy project, since budget is reserved for steel production related projects. The company, however, wants to facilitate the development of this type of projects, and is committed to do so, but does not have CAPEX available for investment. Collaborations with other parties, and investors are searched for. In these projects the interest of TSIJ is not financial, but on the PR side, based on the green image, and environmental benefits the projects entails.

Departments at the TSIJ –site had strict rules & regulations on the control of safety, and the roofs. The internal fire department had little experience with solar panels, and doubted the safety of the installation. The site facilities of TSIJ, the owner of the buildings had their opinion on who owned the roofs, and who had the power to determine the roofs of the projects.

Network

The network of actors of the solar panel project is limited to only three main actors, and one external institution, working together. The project is not influenced by external institutions, and the structure is clear. Tata Steel and Raedthuys have an agreement, not yet a contract on; Raedthuys investing in the solar panels, installing them, and maintaining them for a period of 15 years. Tata Steel has the roofs ready for installation, and becomes owner of the solar panels after 15 years. Tata PV delivers the solar panels for the project. The SDE+ subsidy is requested by Raedthuys and will therefore be paid to Raedthuys.

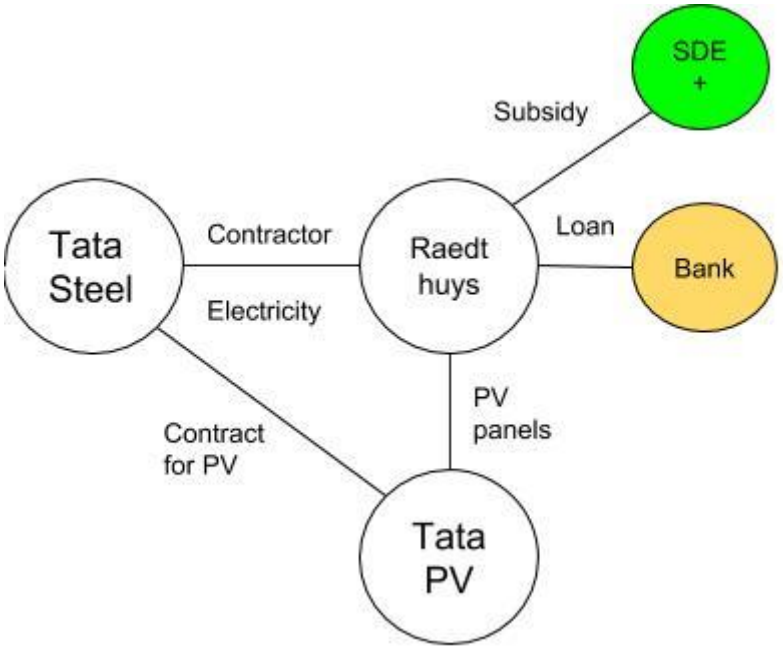

Figure C.3.1 – The network of actors for the TSIJ Solar Panel Project. The SDE + subsidy, and the Bank loan are external factors influencing the collaboration.

Technological Factors

TRL

The project on the development of solar panels looks at the implementation of a proven technology. The TRL is of the technology is therefore **TRL 9.** Just as is the case for the Wind Park Ferrum case, the TRL scale looks at determining the level of development of the technology, and does not include to actual introduction of the technology in its environment. It is impossible to test the applicability, simply because the technology cannot be tested in a pilot phase. Therefore, technological feasibility studies have taken place to assess applicability of the panels in the environment. The implementation of the solar panels in this case caused problems, since a part of the roofs aimed for in the project, had to be replaced, before the panels could be build. This caused uncertainty on the availability of the roofs.

Potential

The total potential of the solar panels for which SDE+ subsidy was requested is 22 MW, with a total area of 25.000 m^2. This only states the capacity of the solar panels. The total generation of electricity is dependent on multiple factors influencing the generation. The factors that are important for calculating the yield of the solar panels, and the data for these values used in the TSIJ calculations are presented in the following table.

Factor	Value
Annual Peak Solar Hours	1000 peak hours / year
Potential of the Solar Panel	300 Wp (0.3 kWp)
Angle of Installation	Not Considered (35°angle assumed)
Orientation of the Panel (No, So, Ea, We)	0.85 is compensation factor for not South oriented roofs
Number of Solar Panels	80.0000

Figure C.3.2 – The factors of impact of the yield of the solar panels, and the values for these factors used in the TSIJ case.

The following formula can be used to calculate the generated electricity:

$$Annual\ Yield = Number\ of\ Peak\ Solar\ Hours\ \times Potential\ of\ the\ Panel \times Number\ of\ Panels\ \times Compensation\ factor$$

This lead to an electricity generation value of:

$$Annual\ Yield^{13} = 1000 \times (0.3 \times 80.000) \times 0.85 = 20{,}4 \times 10^6 kWh/year(\frac{20{,}400MWh}{year})$$

This is an equivalent of roughly 1% of the total electricity use of the TSIJ –site.[14]

Economic Factors

The initial financial benefits for the actors in the networks were clear. Tata Steel would not invest in the solar panels, would bear an income in terms of roof rent over the years (year 1-15), and became the owner of the solar panels after year 15 (year >15), at zero costs. Raedthuys would invest in the project, and become the owner of the solar panels. Raedthuys would receive SDE+ on top of the electricity price. Raedthuys would sell the generated electricity back to Tata Steel at market prices.

[13] The annual yield is an equivalent of roughly 5.800 households per year.

[14] Based on an annual electricity demand of the TSIJ –site of $2{,}1 \times 10^6\ MWh\ .\ \frac{20{,}4 \times 10^6 kWh}{2{,}1 \times 10^6\ MWh\ .} \sim 0.01$

Step 2 – Level of Development

In step 2 the phase of development of the project is explained, based on the current status of the project, and the steps that were taken during the development of the network. If a project plan was used by Tata Steel, the project plan is presented to show how the project was structured.

The first contact between Raedthuys-TSIJ was already back in 2013. The first negotiations lead to signing the first LOI in 2014. The LOI showed the intent to request for subsidy, and to research the availability of rooftops for the solar panels. This lead to the next step of development by trying to apply for subsidy, and draft a business case for the solar panel project. The SDE+ subsidy was granted in March 2015. A second LOI, to work together on finishing the project was signed in February 2016. This was supposed to lead to the draft of contracts in June 2016. Different factors, negatively influencing the project occurred, causing delays in the project (discussed in Step 3- System Failures)

The project is momentarily on a hold, since the finances needed to invest in the project are not present in the network. April 2018 was set as a target for the project to be finished, due to the start of the SDE+ subsidy, but this goal was not reached. Based on the project planning, used by Tata Steel and Raedthuys (Figure 4.8), the project is currently in the Preparation Phase (D). The LOI is signed, and all the technological feasibility studies are conducted for rooftops, grid connections, and electricity transport. The construction of the solar panels, however, did not start yet, due to problems that are described in the next step.

Stage	A	B	C	D	E	F	G
Name	Contracting	Engineering	Tendering	Preparation	Construction	Start Date SDE+	Operation
Action	Between TSIJ & Raedthuys	Electro technical, Supporting Power, Roofs, Fire Safety	Of constructi on companies	Of the roofs and grid for installation of solar panels	Solar Panels	Start date of subsidy grant	Operation of the system in its environment

Figure C.3.3 – The project plan for the development of the solar panel project, used by Tata Steel and Raedthuys.

Step 3- System Failures

In step 3 the system failures are discussed based on findings in documents concerning the project. The words in **bold** are specific facilitators, and barriers, found in these documents. The specific factors that influenced the system negatively provide an insight into where the project was hindered, and what caused failures in the development of the network. Along the project, different factors occurred, that caused delay in the development of the project.

At first, **a fluctuating APX price** caused the electricity price to drop below the lower SDE+ price[15]. The floor price was set at 44 EUR/MWh, but the fluctuations caused the APX price to drop to 25-42 EUR/MWhr in June 2016. The drop below the APX price caused the IRR of Raedthuys to drop below 15% on the project, threatening the feasibility of the business case.

Tata Steel offered support by suggesting to pay a percentage on top of the electricity price. Later, even a drop of the rooftop rent that Raedthuys had to pay was proposed, in order to solve the business case problem. The negotiations, and uncertainty about the electricity price, however, caused a delay of about half a year.

[15] The SDE + subsidy is explained in Appendix H

A second factor that caused delay in the project is a report that came out on **status of the rooftops** that support the solar panels. The report showed that roofs to an equivalent of 9 MW (out of 22 MW) had to be replaced, before the life time of the project of 25 years, was over. The outcomes of this report caused a potential investment in the replacement of the rooftops. Besides the potential investments, the report caused new negotiations on which actor was responsible for the financing of the rooftop replacements and whether this was part of the contract, or not. Solutions were looked for by trying to bring forward the replacement investments of rooftops by Tata Steel, in order to start the project. Up to this date, however, no progress was made in solving the problem of the rooftops.

The two factors presented are both caused by an event that is beyond the power of the actors in the network. The electricity price is subject to fluctuations causing problems with profitability, and the replacement of rooftops could be necessary due to age. The delay arising because of the events is, therefore, understandable, and could not have been avoided. Other factors, however, not related to events beyond the power of the actors, caused problems in the projects too. The factors are discussed in Step 4

Step 4 – Lessons Learned

The lessons learned from the solar panel project at the TSIJ site are deducted from the interviews:

- The first lesson learned was that the **partner selection** for the solar panel project was not set up properly. There were no criteria for the partner selection, and only a quick scan of the partner was performed. An initial request for a subsidy and a project of 3MW was made, but there has not been an assessment of whether the partner was big enough, and skilled enough to conduct a project of 22 MW. The selection was based on experience of the partner with wind parks, and smaller solar panel projects. A clear procedure, like the procedure used in the Wind Park Ferrum project would have made the selection of partners better suited for the project.
- An indication of **the amount of time** that is available, the **role of the actors,** and **the commitment** of all actors should be made at the beginning of the project. Not all departments at Tata Steel internally had the time to work on the project, which caused a delay in the project. This should have been clear at the beginning of the project. The project should have the following steps (according to interview 4): Who are involved in the project? What is their role in the project? What time do they have to work on the project?
- **Commitment of the management**, but also the actors working on the projects is key in project that are not related to steel production. For example, solar panels, are seen as a 'nice to have' project, since it's an add- on. All doubt in the project can be seen as a barrier to the project, and a reason to stop the project. This commitment was shown during the project by the actors working on the projects. Their commitment for instance, made the factory managers committed to install the solar panels on their roofs.
- The **lower business case**, and **the absence of roofs** for the solar panels were the real bottlenecks of the project. The factors are out of the power of the actors, but the way in which they were handled should have been different. A problem solving attitude, as was displayed in the wind park Ferrum project, was not displayed.
- All potential risks in the project were included in the contract negotiations, which caused the contract negotiations to last for 1.5 years. The commitment, and certainty about the project declined. **A different way of negotiation**, in which the risks are mentioned, but an agreement is proposed to re-negotiate ones a risk occurs, could have made the negotiations shorter (according to interview 11 & 15). This increases the risk of mediation, and disturbed relations once a risk occurs, but shortens the contract negotiations.

C.4 Creating a DH –network in IJmond Region

Introduction into District Heating in the IJmond region

In process of steel making, the generation of waste heat is inevitable. Momentarily, roughly said, three options are present for the application of the produced waste heat. Either the heat is lost, either the heat is captured to be re –integrated in internal processes, and other internal applications, or the heat is used for external applications, such as a DH –network. The application of heat in internal processes has the priority for Tata Steel, but the growing number of projects, and the increased interest in the development of district heating networks shows a potential for external applications of waste heat.

The external application of waste heat is not present as of yet, but Tata Steel is active in a network of actors aiming to develop a district heating network for the IJmond region. The trigger to look for the possibilities of a DH –network was given by Gerard Jagers (Tata Steel), and a local councilman supporting the development of a DH –network in the IJmond region. Besides this, a good score (B) for heat produced in Tata Steel processes on the Warmteladder[16] of the MRA, caused an incentive to look for options of heat application.

The actors working on the DH- project in the IJmond became part of a larger collaboration within the MRA aiming to develop a regional waste heat network. The larger collaboration is working on the 'Grand Design' of the MRA, a plan in which 32 organizations work together on the development of regional heat network (MRA, 2015). In the original Grand Design, multiple large heat sources, around 100 MW, are connected through a 'backbone' of heat infrastructure, creating a regional heat infrastructure by connecting multiple large heat sources. The amount of waste heat available from TSIJ was estimated at around 70 MW, roughly enough to heat around 50.000 households[17]. The available waste heat of TSIJ was labelled with B –level in terms of sustainability by the MRA. The 70 MW estimation, in combination with B- level sustainability of heat, caused the waste heat of Tata Steel to be a potential heat source in the 'Grand Design'.

The idea of the 'Grand Design' fell apart in different smaller projects, instead of creating a big regional heat network. Besides this, the waste heat potential of TSIJ was adjusted downwards to the order of magnitude of 20-55 MW. Therefore, the aim of the collaboration is to develop a DH –network in the IJmond region, supplying heat to potentially 10.000 households.

In this paragraph the network of actors working on the project of developing a DH –network in the IJmond region is discussed. In the network the supply, transportation, demand, and regulatory authorities have to be combined.

[16] De Warmteladder MRA is a table presenting the sustainability of heat present in the MRA. The ladder is determined by TNO/ECN, and meant to indicate the sustainability of heat in an understandable and easy way. An indication of B means 15-30 kg CO_2/MJ of heat (Kalkman & Menkveld, 2017)

[17] 70 MW continuously is 6.1x10^5 MWh, which is roughly 2.2x10^6 GJ. The average usage of heat is 42 GJ/household/year (35 GJ heating + 7 GJ water**)** 2.2x10^6/42 = 50.000 roughly estimated.

Step 1 - Structure

Actors

***Tata Steel**:* Tata is a potential heat supplier in the IJmond heat grid, due to the available heat from steel production processes. For the DH – network the heat generated at the Hot Strip Mill (HSM) is assigned, which is in the order of magnitude of 20-55 MW. Tata Steel only acts as a heat supplier. The decoupling of heat from the systems, the development of the infrastructure, and the investments, are done by other actors in the network. Tata Steel supports the idea of an open network, since this prevents a situation in which Tata Steel is the only supplier of heat, thereby creating an obligation to deliver.

***OD IJmond**:* The OD is the permit issuing authority for the middle, and small business in the IJmond region, representing a total of 17 municipalities. Besides being the issuing authority for smaller business, the OD has an advisory, preparatory role, and executing role in local environmental projects. In the DH –network, the OD IJmond acts as a facilitating actor, and the initiator of the network. For instance the draft of a LOI is initiated by the OD, and the OD approached different actors to start the trajectory towards the regional heat grid.

Alliander DGO: Alliander is the overarching name of Liander (DSO), and Liandon (Complex Infrastructures), and operates electricity, and gas grids in specific areas in the Netherlands. Alliander DGO is subsidiary of Alliander, looking for options on sustainable area development by developing open grids for the transportation of heat, and renewable energy. The company supports the idea of creating a heat grid in which multiple heat sources can be combined. Alliander DGO was approached by the OD IJmond to look for the development of the infrastructure for an open heat network in the IJmond region.

***HVC**:* HVC is a trash processing, and energy company, partly owned by 46 municipalities. The company was approached by the municipalities of Heemskerk, Velsen, and Beverwijk to provide their part in the heat grid construction. HVC should take care of the subtraction of the heat from the Tata Steel processes. Besides this, connect the supply of heat to the demand (TSIJ to Housing Corporations). HVC has appointed a consultant for the project that has been interviewed about the collaboration.

Housing Corporation (PreWonen, WOONopMAAT, Woningbedrijf Velsen, Velison). The housing corporations are the potential purchaser of the heat, since the houses in their property will be connected to the heat grid. By choosing housing corporations it is possible to connect a larger group of houses to the grid at the same time.

Province of Noord – Holland: The province of Noord –Holland is the permit issuing authority in the development of the heat grid, but is not actively involved in the development of the local heat grid. This role is left to the OD IJmond. The Province has a monitoring role in the development of the project, and acts as an advisor when needed. The Province is busy with setting up a platform for shared learning on the development of DH –networks, and aims at indicating what potential sources of heat are available within the province.

Institutions

External Institutions

In the development of a DH –network, multiple external institutions are influencing the development of the infrastructure. Although Tata Steel only acts as a supplier of heat, an insight into the institutions influencing the project is provided. Heat networks are intended to replace natural gas networks, by providing heat for home heating, and water heating. The presence and absence of institutions is influencing this replacement. The presence of the Gaswet, and the absence of clear regulations on DH –networks are discussed.

Gaswet

The Gaswet is the law that regulates all natural gas usage in the Netherlands. In the law, a provision is included which obliges the network operator to connect households to the gas grid, causing 95% of the Dutch households to be connected to the gas network. As long as this obligation stays present, there is no direct incentive to change from natural gas to heat networks, or other sustainable solutions. Therefore, the government is looking to change this law, and remove the obligation. This would put more attention on replacing natural gas, and create an incentive for DH –network development (van Santen & van der Walle, NRC, 2018). Until the obligation is changed, houses have to be connected to the gas network.

Absence of Regulations

The Warmtewet is present, which covers the heat distribution to households, but is mostly intended to protect individuals from too high prices for heat, and to regulate the compensation for network failures(Wit, 2011). The law includes the NMDA -principle[18]. This principle states that the heat price paid by a household cannot be higher than the price currently paid for a gas fired boiler (PBL, 2017).The price of heat is connected to the gas price, therefore, subject to fluctuations in the gas price, that have nothing to do with heat. As long as this connection stays, the profit of a heat grid is marginal for the heat delivery companies.

Besides the Warmtewet, no policy, or regulations are present in the Netherlands, regulating the development of a heat network. The absence of laws on the one hand, gives an opportunity to anyone willing to develop a heat network. The freedom gives all actors the opportunity to develop a heat network, monopolize this, operate it, and sell the heat. No law is present, preventing companies to construct heat grids. Therefore, the heat market is not regulated, and any party willing to invest in a heat network is allowed to, as long as they are granted permission by the Dutch market authority.[19] This has a results that the heat networks are developing in a scattered way, and are not based on a structured, government regulated process (PBL, 2017). The government has a monitoring role on the development, and the actual facilitation should be led by the local, and regional governments.

[18] The NMDA principle means the Niet Meer Dan Anders principle.

[19] The Dutch Market Authority is the ACM; Autoriteit Consument & Markt. This authority supervises the Dutch consumer market.

On the other hand, uncertainty rises on the future of heat network development, due to the absence of regulations. The uncertainty is based on the fact that no regulations steering the future development of heat networks are present. Currently, the development of the district heating networks progresses in a scattered way, with a limited margin on the investments. What if, however, the government decides to make the heat networks public infrastructure, operated, build, and maintained by a system operator (PBL, 2017). This would change the investment decisions. Private investors momentarily stall their investments in heat network development, based on the uncertainty of the future regulations (van Santen & van der Walle, 2018).

The absence of regulations further causes uncertainty, and a marginal business case for different actors in the heat supply network. For the producers of industrial rest heat (like Tata Steel), there is no regulated incentive to engage in a heat network, because no heat price indication is present. For the industrial heat suppliers potential incentives could be (PBL, 2017):

- Make the handling of heat by industrial companies publicly known, which could make the re-use of heat an image driven process.
- Make the dump of heat, which is currently the most used option, less easy, by installing stricter conditions
- Make the re –use of heat count as an energy saving of the supplier of the heat, causing an energy reduction incentive for the supplier.
- Focus on the development of Open Heat Network, in which the industrial supplier is not the only heat supplying company. The heat supply does not have a big of an influence on the primary production processes anymore, since the supplier is not constantly obliged to deliver heat, but could stop the delivery when needed. The residual demand will be covered by other actors.
- Reward the supplier of heat for the CO_2 reduction that is achieved by its heat outside of the company. For instance by issuing extra emission rights
- There is no regulated incentive to deliver heat to a heat network. Some incentive for industrial heat delivery could be: making the dumping of heat less easy, make sure the rest heat is counted as energy reduction, give the potential of an Open Heat Network, make sure extra emissions rights count for the delivery company

The above mentioned options are only focussed on the industrial heat suppliers, due to the role of Tata Steel IJmuiden as a potential supplier of heat.

Internal Institutions

Different internal institutions, drawn up by Tata Steel influence the development of the DH – network. The first is, Tata Steel produces heat, but will not act as a heat company. The company provides the heat, but has asked other parties (HVC, Alliander DGO) to distribute and sell the heat. Therefore, the company is in favour of creating an Open Heat Network in which different heat sources are connected to the network. This prevents the ‘lock-in’ of Tata Steel as a heat provider to the grid, since other parties could replace the heat supply of Tata Steel, during downtime, maintenance, or faults at the TSIJ facility supplying the heat.

The second is, the internal merit order for the re-use of heat. Tata Steel will try to reduce the amount of waste heat production as a first step. If waste heat is produced, the company will try to use the heat internally first, after this external solutions are looked for. This shows the potential of heat for a district heating network, but also the competition with potential internal applications.

Network

The network of actors collaborating on the development of the heat network in the region of IJmond exist of actors, supporting different roles. The different actors, and their relationships are represented (figure 4.8). The structure of the network is slightly different from the previous two networks presented. This is caused by the fact that the network is in the beginning stages of development, and not all connections and roles are clear as of yet. The suppliers of heat are not determined yet, this could by Tata Steel, Floricultura, but also other sources of heat in the region. The roles of the infrastructure companies (HVC, and Alliander DGO) in relation to Tata Steel are not defined precisely yet, but are presented in the paragraph Actors.

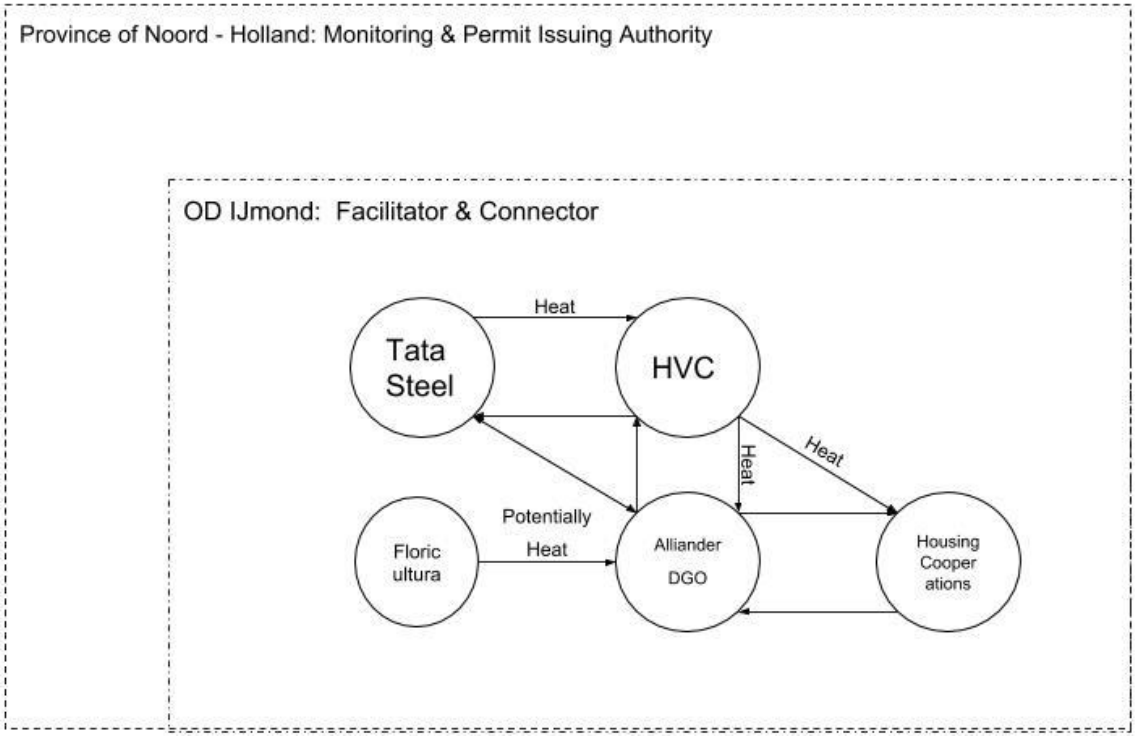

Figure C.4.1– The network of actors working on the development of the DH – network in the IJmond region. The province of Noord- Holland, and the OD IJmond are the governmental organizations involved in the project (represented by the dotted lines). The actors are connected by multiple edges, showing the uncertainty in the final structure of the network momentarily.

Technological

The technological characteristics of the project are divided in the TRL of the technology, the market background of the DH –network, a technological introduction into heat transportation, and the technological background of the heat generation, and subtraction at Tata Steel.

TRL

The project on the DH –network in the IJmond aims to develop a heat network. The technology of the heat networks is proven, and the TRL of the heat network is TRL 9. A remark must be made, however, on the technological development of an Open Heat Network. In these Open Heat networks, heat of different temperatures will be supplied to the grid, and divided over users with different heat temperature demands. In the heat network, 'Cascadering' needs to take place, coupling users with a demand for high temperature heat, to users with a demand for low temperature heat. The high temperature users will receive the heat first, for instance, and the low temperature users will receive the heat after, in this sense a stepwise structure emerges from high to low temperature demand (PBL, 2017).The current heat network are build based on one supplier connected.

Heat Networks

The heat supply chain can be split up into three different parts: Generation, Transport, and Distribution. Two different designs exist that connect these three parts; a closed network design, and an open network design. In closed networks, the whole supply chain is owned by one company, with one source of heat, which results in absence of choice in heat supplier (PBL, 2017).

In open heat networks, most of the time, all parts of the supply chain are executed by different actors. A heat supplier, an infrastructure operator, and a retail company are present. This design causes higher administrative costs, but more shared network, and investment risks(Onate, 2015).

The network operators in the Netherlands have shared a vision on the future of heat networks. In this vision, the future of heat networks in the Netherlands will be based on publicly owned Open Networks. The design of the network is similar to the already existing electricity, and gas market designs in the Netherlands. A network operator is in charge of the creation, operation, and maintenance of the heat network, while multiple different suppliers are connected to the heat network. Cascadering of the heat takes place, connecting different temperatures of heat, to different temperature demands. These networks present the opportunity of Third Party Access to the network, and potential competition between heat providers in the future. (PBL, 2017). The competition is caused due to the potential access of multiple sources, such as a mix of geothermal sources, industrial heat sources, and waste incarnation, meaning an open heat network. ("Warmtenetten in publieke handen," n.d.).

The transportation of heat

The transportation of the heat in heat network happens in three different ways; steam, hot water, or thermal oil. At temperatures of 120-130 degrees (in the form of steam) from the supplier to a substation, and at a temperature of 90 degrees from the substation to the household, or other end-user. The water (in this case) used is returned at a temperature of 70 degrees to the industrial plant (Ennatuurlijk, 2018). Predictions even state the possibility of a heat network supplying 40-55 degrees Celsius heat, based on future lower temperature supply, and lower heat losses during transportation (PBL, 2017).

Characteristics Tata Steel DH –network

When looking at the IJmond Heat Network, the role of Tata Steel of the heat supplier. All activities after the generation of heat, are performed by other actors. The problem of the industrial heat supplier are momentarily caused by the fact that the decoupling of heat needs to be integrated in the production processes of the company. Also due the fact that the heat supply is not profitable, due to absence of a clear heat price (PBL, 2017).Tata Steel has allocated heat sources of different steel production facilities at the TSIJ-site. In the scenario for the IJmond Heat Network, the ovens of the Hot Strip Mill (HSM) will function as suppliers of heat in the form of flue gas.

Within these ovens a valve is installed from which the flue gas at a temperature of 350 degrees Celsius, is sucked by a suction –pull fan, preventing this gas to leave the oven through the stalk. All the operations after this valve are for the party that is presented as; the heat company. In an initial idea, the flue gas is sucked towards waste gas kettles in which steam will be created for the heat network. This steam is created at 3,5 bar at a temperature of 185 degrees Celsius.

The valves can be closed by Tata Steel once the HSM is hindered by the flue gas being withdrawn from the process. This causes the flue gas to leave the oven through the stalks. Each oven has a heat capacity between 6.5 – 8.7 MWh/h. By coupling all 3 stalks, the capacity can be combined. The expected capacity is 10MW for 1000 hours/year, with a range between 20-55MW for 7000 hours per year.

The potential of the heat produced by the HSM as an input for the DH –network is presented, but also the necessity of other sources in an open network. These sources are needed in order to prevent a lock –in. The HSM generates enough heat for the DH –heating network for most of the year, but the possibility to shut the delivery of heat down, needs to be present. Other sources of heat are necessity in the network, asking for the development of an Open Network.

Economic

Tata Steel acts as a heat supplier to the grid. Therefore, only the price of the heat is considered as an economic factor in the development of the grid, from Tata Steel perspective. As of yet, no standard price for waste heat has been determined, but in recent years waste heat has become a full product, instead of only a waste stream. Waste incinerators, electricity plants, and heat connecting plants are selling their heat to regional heat grids. For small users (100kW) there is a maximum price for the heat, set in the Warmte Wet, but for large users the heat price is free[20]. A first indication of a heat price was set at 4 euro/GJ for the heat from Tata Steel to the supplier

Not many methods to indicate the price of industrial heat are present, however, an indication based on the electricity generation. If the heat is generated during electricity generation, the price is determined by looking at how much less electricity is generated due to the simultaneous heat generation. The loss is about 14%, and the estimated price for the heat is 0.014 Euro/kWh (Gudmundsson, Thorsen, & Zhang, 2013). This price is an equivalent to roughly 3.9 euro/GJ, which comes close the first indication of 4euro/GJ. Other studies are already talking about a market model of heat pricing, in which the price is determined based on the total demand of heat, and the total supply (Hailong Li, Fredrik Wallin, 2017). This situation is based on a future centralized market model. The maximum heat price for a consumer is determined at 25.4 euro/GJ in 2018 (ACM, 2018). The heat price paid to the supplier could be a margin of this price, based on an equal distribution along the heat supply chain. .

[20] Decentralized Energy on District Heating in 2016 (https://www.decentralized-energy.com/articles/print/volume-17/issue-1/features/times-are-changing-for-district-heating.html)

Step 2 – Phase of Development

In step 2 the phase of development of the project is explained, based on the current status of the project, and the steps that were taken during the development of the network. If a project plan was used by Tata Steel, the project plan is presented to show how the project was structured.

In order to create the DH –network, already in 2014 collaboration existed of: Tata Steel, Province of Noord-Holland, Municipality of Heemskerk, Beverwijk, Velsen, OD IJmond, Alliander DGO, Veolia, and the housing corporations. The parties agreed on a DOI in 2014, in which all parties agreed to provide their part. For TSIJ this meant that the company had to determine the role they wanted to play in the project. Besides this, internal studies had to conducted to find out the potential

The internal studies were conducted to find feasible heat sources to supply heat for the regional network. Included in these studies are a rough economic analysis of the costs, and a technological analysis used to indicate the feasibility of the heat sources from a technological, and economic perspective.

In the collaboration, the next step on the agenda was a declaration of collaboration. In the declaration of collaboration the clear tasks and the goal of the collaboration would have been included. Besides this, the declaration would have made the collaboration less without obligation.

At this point, however, the municipalities present in the network wanted to replace Veolia/Ennatuurlijk (a heat network company) with HVC (a waste & energy company owning heat networks), which meant the replacement of an actor in the collaboration. This caused a delay in the whole process of roughly a year. Momentarily talks are going on for a new declaration of intent, of which a preliminary version has been drafted.

To conclude, the level of development of the network is currently based on the fact that the new DOI is drafted, but not signed yet. The network made a step back in development, due to the change of an actor. Initial meetings between the actors have taken place to work towards to DOI.

Step 3 - System Failures

In step 3 the system failures are discussed based on findings in documents concerning the project. The words in **bold** are specific facilitators, and barriers, found in these documents. The specific factors that influenced the system negatively provide an insight into where the project was hindered, and what caused failures in the development of the network.

Different system failures or success factors occurred during the network development:

- The change of company, initiated by the municipalities, caused a delay in the process, and new negotiations on the development of the heat network to be necessary.
- There are competing heat applications for the heat source of the HSM stacks. Internal heat recovery has a higher place in the internal order than the supply to external heat networks. If future decisions decide to change the availability of heat to the external network this could cause problems. Therefore Tata Steel wants to have a network with back-up.
- The validation of heat supplied by Tata Steel is difficult, since heat was formerly treated as industrial waste energy, and not re-used. No economic value to the heat has been assigned as of yet, making a business case draft, and further calculation of investment and ROI hard.
- The heat grid developers in the network of for the development of the IJmond Region Heat Network both indicate that the governmental regulations on the future heat market cause uncertainties in the current development of heat networks. The government has to provide clarity in order to structure and incentivize the development of larger scale heat grids. The province signals missed chances in the development of heat grids, due to the marginal business cases for the companies developing the heat networks, caused by the uncertainty.

Step 4 – Lessons Learned

Due to the beginning phase of the new network, there are no lessons learned yet in the network. Based on remarks by interview respondents some lessons learned regarding the development of heat networks could be provided:

- The province of Noord-Holland has a monitoring role in the development of heat networks, whereas the local authorities are the leading authorities. The local authorities combine actors, function as a facilitator, and are capable of representing the common interest. The province, due to its monitoring role, has extensive knowledge on successful and failed cases. The province could function as a knowledge institute in current cases of heat network collaboration. They notice however, that this possible role is not taken often, and actors in the current networks are not making use of the knowledge present. The province, therefore, propose the possibility to contact them with questions, or when the development of the network is hindered. The role of the province thereby could be bigger, then monitoring the development.

C.5 Map of TSIJ

The map of Tata Steel IJmuiden , used to indicate the outline of the site, and indicate the position of Wind Park Ferrum, at the western border of the site.

Figure C.5.1 – Map of the TSIJ –site. The red rectangle indicates the location of the three wind turbines of Wind Park Ferrum

C.6 Policy Scales

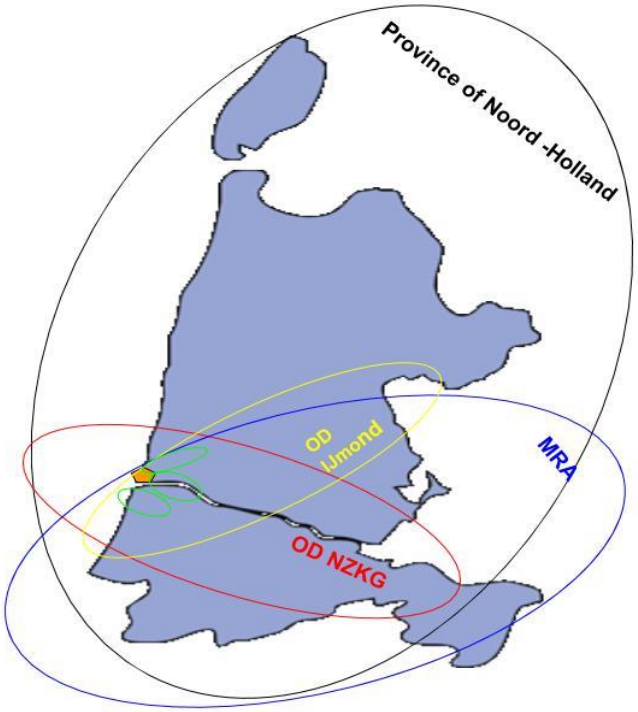

Figure C.6.1 – Tata Steel IJmuiden (the orange pentagon) is located in the Province of Noord – Holland. Different layers of policy, however, influence the development of renewable energy projects and waste heat. The layers are indicated with by the coloured ellipses.

Tata Steel IJmuiden is influenced by different governmental organizations in the projects for renewable energy and district heating. The different scales of policy are presented in Figure G.1. The role of the different layers is presented.

Province of Noord – Holland: The decree for 'Wind on Land' determined the search locations for new wind parks. The province was the authority giving out permits for the development of the wind park Ferrum. Besides this, the province was the supervising authority for the development of the DH –networks in the province (included the IJmond heat network).

MRA: The Metropoolregio Amsterdam is a collaboration between 2 provinces and 33 municipalities on economic projects in the region. The MRA facilitated the 'Grand Design' of a heat network throughout the MR, combining different smaller heat networks.

OD NZKG: The Omgevingsdienst Noordzeekanaalgebied facilitated the permit procedure for Wind Park Ferrum on behalf of the Province of Noord –Holland. Collaboration for the permits took place between Tata Steel, Infinergy and the OD NZKG.

OD IJmond: The OD IJmond represents 15 municipalities on environmental topics. The OD Ijmond facilitates the development of DH –network in the IJmond region, by connecting the actors in the network.

Municipalities: The TSIJ –site is located within the borders of the Municipalities of Beverwijk, Velsen, and Heemskerk.

Appendix D

Interviews

D. 1 Interview Structure

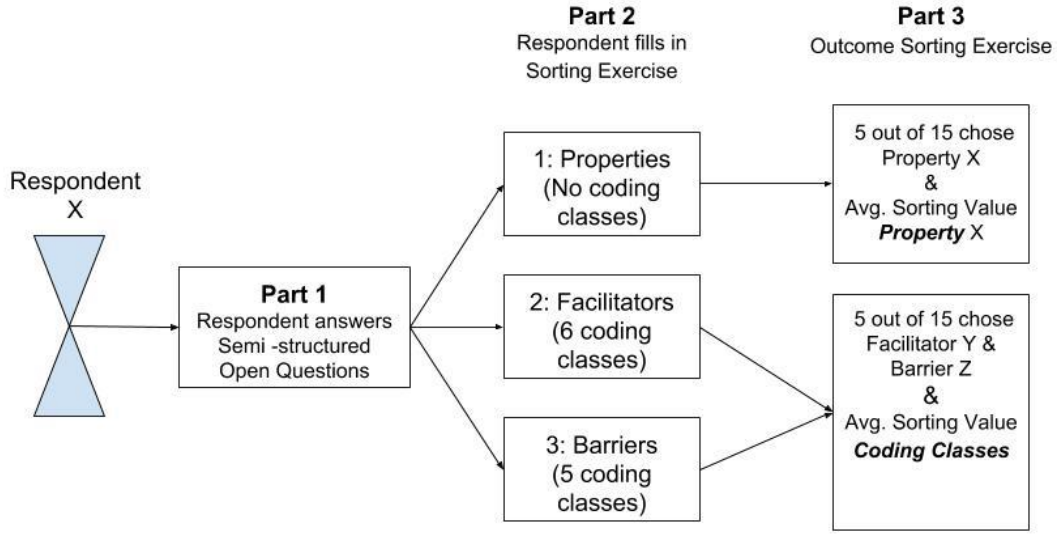

Figure D.1.1 – Graphical representation of the interview structure. All the interviews started with Open Questions on the network in which the actors are/were active (Part 1). This is followed by the sorting exercise (Part 2). The sorting exercises of the Properties, Facilitators and Barriers were presented one by one. The outcomes of the Sorting Exercises (Part 3) differ, due to the different structures used.

D.2 Difference in Outcome of the Sorting Exercises

The sorting exercises of the Properties, and the sorting exercise of the Facilitators & Barriers were differently structured. The different structures lead to different outcomes. The outcomes are explained in this Appendix.

Sorting Exercise Properties

The sorting exercise to obtain the most important properties contained fifteen properties. No further coding classes were used to structure the sorting exercise. Each respondent had to pick a top 5 of properties (1 = most important, 5 = least important), which lead to two different results:

- Number of times chosen value for the property: (Number of Times chosen / Total Number of Respondents). For example, the presence of a Central Coordinating Actor is chosen 5 times, while there were 15 respondents, leading to a value of 5 out of 15.
- The Average Sorting value of the property: (Total Score of the Property / Total Number of Respondents). For example the property of trust receives a total of 51 points,[21] while 15 respondents were present, the average sorting value is $\frac{51}{15}$ = 3.8.

Sorting Exercise Facilitators & Barriers

The sorting exercises of the Facilitators & Barriers were both sub-divided into 6 and 5 different coding classes, obtained from the theoretical framework on network development (presented in paragraph 4.1). The sorting exercise of the facilitators consisted of the following coding classes: Collaboration, Communication, Political, Technology, Economy, and Geographical. The specific facilitators were presented under these coding classes. The sorting exercise of the barriers consisted of the following coding classes: Collaboration, Communication, Political, Technology, and Economy. The specific barriers were again presented under the coding classes.

The respondents were asked to rank the coding classes in order of importance (1 = most important, 5= least important), besides this the respondents were asked to pick the specific Facilitators & Barriers they considered important. This lead to two different results:

- An Average Sorting Value for each of the coding classes: (Total Score of the Coding Class/ Total Number of Respondents). For example the coding class of Collaboration received a total of 58 points, while 15 respondents were present, the average sorting value is $\frac{58}{15} = 3.9$
- A number of times chosen value for the specific facilitators and barriers. For example the facilitator of Support by Decision Makers is chosen 4 times out of 15 respondents, leading to a value of 4 out of 15.

On the following page the outcomes are further explained. The outcomes of the sorting exercises are presented in Appendix D.5.

[21] Position 1 in the sorting exercise lead to a score of 5, while Position 5 in the sorting exercise led to a score of 1, which means that the highest position lead to the highest score. A higher average sorting value means a higher ranking according to the respondents. This was both the case for the Properties, and for the Facilitators & Barriers.

Sorting Exercise Properties (2 outcomes)

The number of respondents was 14. The sorting exercise of the properties had two formulas:

1. $Frequency$[22] $= Number\ of\ times\ chosen\ property\ \div Number\ of\ Respondents$
2. $Average\ Sorting\ Value = Total\ Sorting\ Value\ \div Total\ Number\ of\ Respondents$

An example of the outcomes is:

1. $Frequency = \ 6 \div 14 = 6\ out\ of\ 14\ or\ 0.43$
2. $Average\ Sorting\ Value = 58 \div 14 = 4.1$

Sorting Exercise Facilitators & Barriers (2 outcomes)

The number of respondents was 14. The sorting exercise of the properties had two formulas:

1. $Average\ Sorting\ Value\ Coding\ Class = Total\ Sorting\ Value\ Coding\ Class\ \div Total\ Number\ of\ Respondents$
2. $Frequency = Number\ of\ times\ chosen\ Fac./Bar. \div Number\ of\ Respondents$

An example of the outcomes is:

1. $Average\ Sorting\ Value\ Coding\ Class = 50\ \div 15 = 3.33$
2. $Frequency = 6\ \div 14 = 6\ out\ of\ 14, or\ 0.43$

The Average Sorting Value was only calculated for the Coding Classes, the individual Facilitators & Barriers did not receive an average sorting value.

[22] In the text of paragraph 5.1.1 till 5.1.3 the frequency is denoted as 5 out of 15, and not as a decimal number. This was done, since the 5 out of 15 notation gives a clearer view of the result.

D.3 Interview Template

All interviews were accompanied by a letter introducing the research, and explaining the interviews & sorting exercise. The letters were sent before the interview in combination with the template. This gave the respondents the possibility to prepare for the interview. The interview template existed out of seven predetermined Open Questions, and the three sorting exercises.

Interview Template

Open Questions

The following questions will be asked:

1. What is your function within [name of company, or government institution]?
2. How is [name of company, or government institution] connected to the project, or process that will be discussed during this interview?

After these questions, an introduction into the framework for analysing, and assessing networks on renewable energy projects, will be given. Then the following questions will be asked:

3. Can you give three reasons why collaboration in a network of actors was needed during the project concerned?
4. What do you think is necessary to establish successful collaboration between parties (concerning the project)?
5. What starts, or triggers collaboration between parties in the [name of the project] project?
6. Are there any facilitators, or barriers, coming to mind right away, that influenced collaboration during the project? This could be technological, economic, social, network, institutional, legal barriers. Could you state the three most important?
7. In which phase of the projects did these factors occur?

Sorting Exercise

Following these questions the interview will be concluded with a sorting exercise. The idea of the sorting exercise is to structure the interview, and gain insights into the most important drivers, barriers, and properties of collaboration in a network of actors. In the sorting exercise, lists of network properties, facilitators, and barriers are presented[1]. The lists have been divided in subjects, such as; communication, politics, economics, to facilitate the sorting. Also a list of terms is included that clarifies the meaning of some terms[2]. The terms further explained are indicated with *.

If there are properties, drivers, or barriers missing which were essential in projects, please note them. The lists are not exhaustive, and additions are very helpful.

The following three questions will be asked, together with the lists of potential properties, network facilitators, and barriers.

1. Could you pick out five properties of working together in a network that you think are relevant for successful collaboration between parties and sort these five items from 1 to 5. In which the property at place 1 is most relevant, and at place 5 is least relevant.

- Presence of central orchestrating actor*
- Shared vision
- Multi-level collaboration (local, regional, national)
- Actor heterogeneity*
- Trust
- Formal Relationships
- Informal Relationships
- Like minded actors (shared vision)
- Institutional framework to stimulate collaboration*
- Declaration of Intent for Collaboration
- Formal contracts
- Transparency
- Reliability of actors

1. The literature used to draft the lists is presented in the Appendix under [1]
2. The list with the terms, indicated with a * is presented in the Appendix under [2]

2. Could you order the five categories of network facilitators, presented in *Italic, from* 1 to 5? In which 1 is the most relevant, and 5 the least relevant. After this, could you pick out the most relevant network facilitators from each category that you think will facilitate the collaboration of actors in a network?

Communication

- Alignment of interests*
- Convincing plans for collaboration in the projects
- Set targets and goals
- Presence of milestones

Collaboration

- Presence of central orchestrating actor
- Actors willingness to share resources
- Collaboration on different scales*
- Presence of key actors
- Well established relations already from the beginning of the project
- Necessity to work together

Political (Institutions)

- Availability of institutions guiding the projects
- Availability of subsidies
- Support by decision makers (on different levels)

Economic

- Financial gains
- Shared risks
- Possibility to find investors for the projects

Technological

- Related to everyday practices, and believes of the company
- Fully developed technologies at the beginning of the network creation

Geography

- Proximity of actors in the network
- Discovered potential for renewable energy generation
- Network integration (tighter, more centralized network)

3. Could you order the five categories of barriers, presented in *Italic, from* 1 to 5? In which 1 is the most relevant, and 5 the least relevant to collaboration in a network of actors. After this, could you pick out the most relevant network barriers from each category that you think will facilitate the collaboration of actors in a network?

Communication

- Sharing of knowledge is difficult
- Lack of knowledge (staff, authorities, project actors)
- No orchestrating actor present
- Withholding of information

Collaboration

- Lack of involvement by specific actors in the project*
- Internal corporate culture hinders collaboration
- To weak interactions between the actors*
- Lack of trust
- Stepwise and formal process of forming networks of collaboration
- Key actors leaving the project/process
- Conflicting interests
- Too many actors involved (impossible to align)
- Uncertainty about the outcome (stop/go decisions)

Political (Institutions)

- Regulations are hindering collaboration (or the project concerned)
- Legal constraints (permitting procedures)
- Lack of hard institutions*
- Lack of soft institutions (legitimacy)
- Legal uncertainties

Economic

- Increasing costs of collaboration
- Dependency on subsidy, other funding
- Disagreement on the allocation of risks
- Absence of investment budget
- Disagreement on the allocation of costs and benefits

Technological

- Immature technologies (TRL level not up to implementation)
- External implementation problems (technology is present, but implementation impossible)

Extra Information Interviews

1.

Since the networks are energy project related, these drivers, barriers, and properties are collected from various literature sources on; energy regions, regional renewable energy development, TIS (Technology Innovation Systems), RIS (Regional Innovation Systems), transition management, network management, cluster management, and the already existing NRL. Interviewees will have the opportunity to come up with own factors, missing in the lists. The literature sources used to draft the lists: (Lutz, 2017) (Ambrose, 2016) (Newell, 2017) (Lutz, 2017) (Skellern, 2017) (Jacobsson & Johnson, 2000) (Hekkert, 2011) (Rotmans, 2018) (U.S. DoE, 2017)

2.

Central Orchestrating Actor = actor bringing other actors together, initiating collaboration in a network, and keeping the collaboration running

Actor Heterogeneity = presence of actors with different roles in the network, all contributing in their own way to the projects

Institutional framework to stimulate collaboration = some incentive has been started to work together in a specific field, such as collaboration on Heat Networks, collaboration on Renewable Energy Projects in a region.

Translation of Interests = understanding that working together is the only option to execute the projects, thereby trying to align the interests of actors as good as possible

Collaboration on different scales = collaboration on a company scale, but also on regional, and national scales. To incorporate otherwise overlooked actors, and stimulate the projects.

Lack of involvement by specific actors in the project = some actors are not as actively involved in the network as others, they are not taking the projects seriously, and this could eventually influence the progress.

Too weak interactions between the actors = no intensity in the collaboration, loosely coupled relations

Lack of hard institutions = no long term regulations, attention shift in policy, lack of subsidy, many initiatives, but lack of authority on a regional scale

D.4 List of Experts

The list of experts is the same as the three lists presented in Chapter 5, but merged into one table of interviewees.

Number	Role	Tata Steel/ External
1	Project Manager Energy Efficiency	Tata Steel
2	Energy Consultant	Tata Steel
3	Project Manager Wind Project	Tata Steel
4	Actor Solar Panel Project	Tata Steel
5	PR manager Wind Project	Tata Steel
6	DH – network developer	External
7	Representative Common Interests (Wind Park)	External
8	Project Manager Wind Park & Solar Panel Project	Tata Steel
9	DH – network consultant	External
10	Permitting Authority Wind parks	External
11	Project Manager Solar Panel Project	Tata Steel
12	Representative DH – network	External
13	Energy Department	Tata Steel
14	Representative Local Government	External
15	Project Manager Solar Panels	Tata Steel

D.5 Results of the Sorting Exercise

Properties

The results of the properties are divided over two graphs, and a table. The first graph presents the Frequency a property was chosen, and the Sorting Value of the Property (Figure C.4.1). The second graph presents the Average Sorting Value of the Properties (Figure C.4.2) The table presents the number of times chosen value of the Properties (Figure C.4.3).

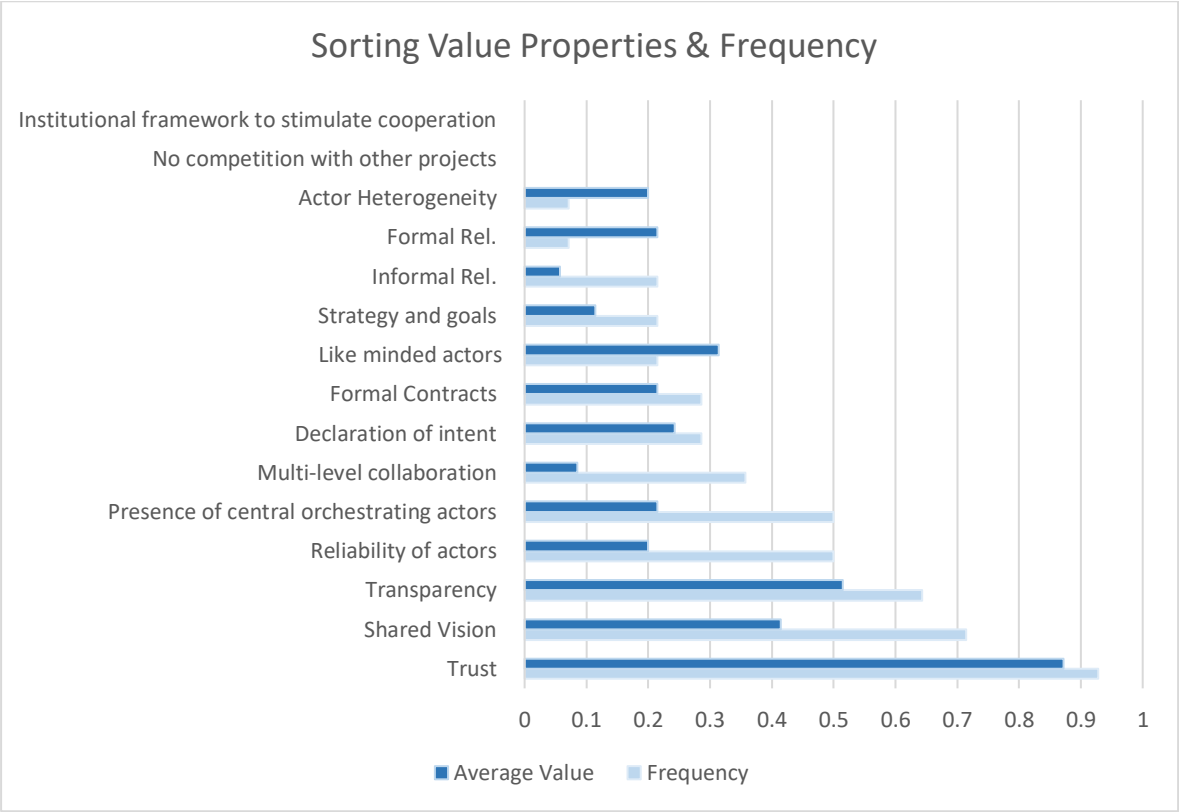

Figure C.4.1 – The Sorting Value of the properties, combined with the Frequency. The Sorting Value is determined by the (Sum All Sorting Values / Total Value Possible (70). The frequency is determined by the (Number of Times Chosen / Total Respondents (14).

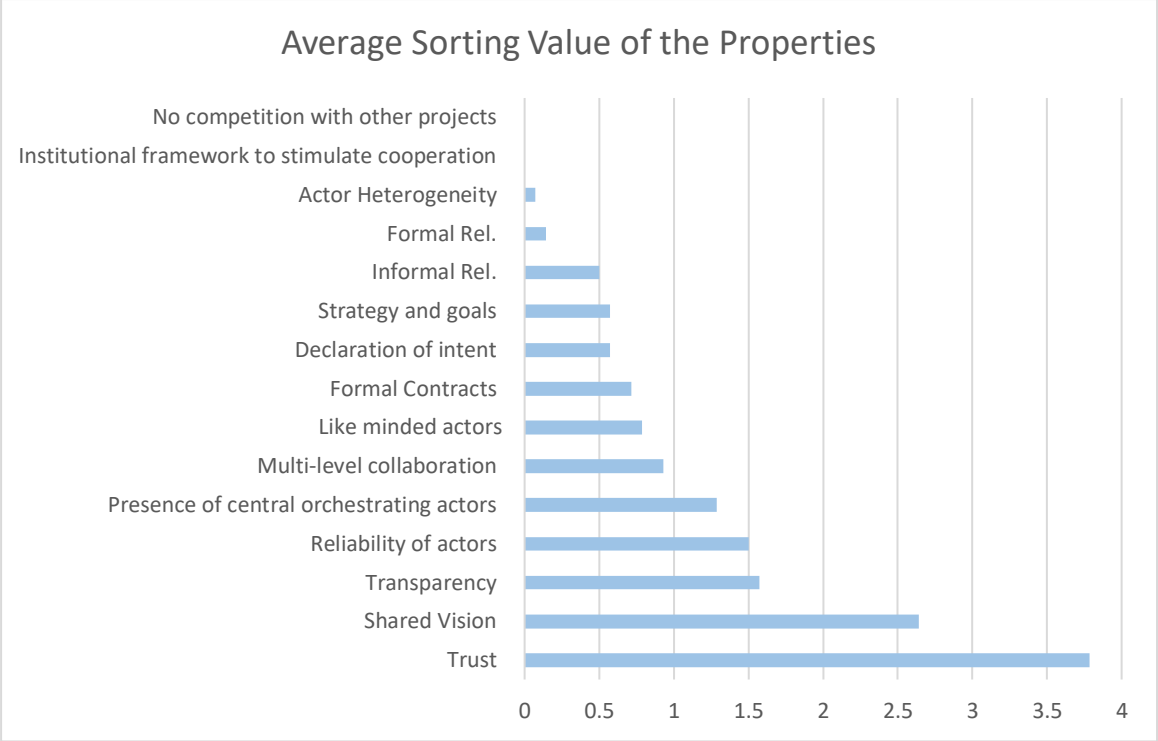

Figure C.4.2 – The Average Sorting value of the Properties. The maximum value was 5.

Properties	# of times chosen
Trust	13 of 14
Shared Vision	10 of 14
Transparency	9 of 14
Presence of central orchestrating actors	7 of 14
Reliability of actors	7 of 14
Multi-level collaboration	5 of 14
Declaration of intent	4 of 14
Formal Contracts	4 of 14
Informal Rel.	3 of 14
Like minded actors	3 of 14
Strategy and goals	3 of 14
Formal Rel.	1 of 14
Institutional framework to stimulate cooperation	0 of 14
No competition with other projects	0 of 14
Actor Heterogeneity	0 of 14

Figure C.4.3 – The number of times a property was chosen by the respondents.

Facilitators & Barriers

The results of the Facilitators & Barriers sorting exercises are presented by a graph and two tables. The graph shows the Average Sorting Value of the coding classes of Facilitators & Barriers (Figure C.4.4). The first table shows the number of times a facilitator was chosen (Figure C.4.5.) The second table shows the number of times a barrier was chosen (Figure C.4.6). Only the facilitators and barriers that were further analyzed are presented in the tables.

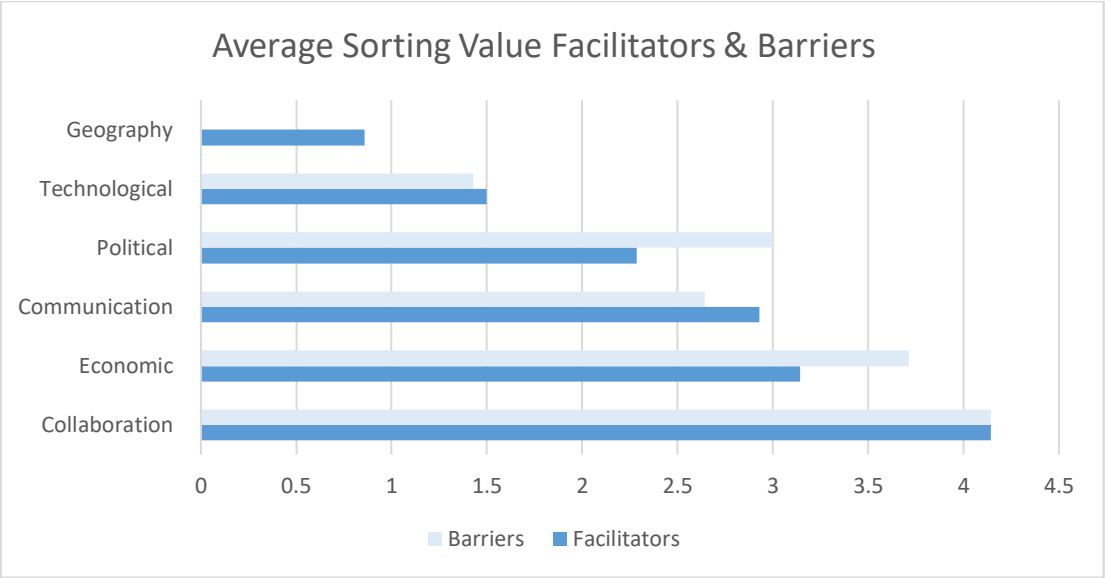

Figure C.4.4 – The Average Sorting Value of the Coding Classes of Facilitators & Barriers. The higher the value, the more important the coding class in a collaboration. Geography was only used as a coding class in the sorting exercise of the facilitators.

Facilitators	# of times chosen
Willingness to Share Resources	12 out 14
Alignment of Interests	11 out 14
Support by Decision Makers	10 out of 14
Central Orchestrating Actors	7 out of 14
Key Actors Present	7 out of 14
Well established relations already present	6 out of 14
Financial Gains	5 out of 14
Set targets and goals	4 out of 14
Shared Risks	4 out of 14

Figure C.4.5 – The number of times a facilitator was chosen by the respondents.

Barriers	# of times chosen
Conflicting interests	10 out of 14
Lack of trust	8 out of 14
Disagreement on allocation of costs and benefits	8 out of 14
Knowledge sharing difficult	6 out of 14
Uncertainty about the outcome	5 out of 14
Legal uncertainties	5 out of 14
Legal constraints	4 out of 14
Disagreement on allocation of risks	4 out of 14
Withholding of Information	4 out of 14
External implementation problems	4 out of 14

Figure C.4.6 – The number of times a barrier was chosen by the respondents.

Appendix E

The interpretation of the properties, facilitators, and barriers

In Appendix E, the properties facilitators, and barriers that were not used as an example in paragraph 6.2.1 till 6.2.3 are presented. The same structure of interpretation is used. At first, the PFB is connected to theory, followed by a connection to the expert opinions expressed during the interviews. More PFB's are added based on these opinions. As a final step, a motivation to indicate the PFB in a specific level of development is provided. To prevent confusion, the examples already used, **are** included in the appendix. The description starts again with the properties, followed by the facilitators, and finished with the barriers. The final outcome of the interpretation of the properties, facilitators, and barriers is presented in Table 1 in paragraph 6.2.4. The coding classes used for the Facilitators & Barriers are presented in Blue.

E.1 Properties

The properties of collaboration are presented by mentioning the properties one by one. Properties mentioned in the remarks of the respondents are presented in **bold.**

Formal Contracts

Theory

4 out of 14 respondents mentioned **formal contracts** as a property of collaboration. Contracts are the formalization of trust between actors, leading to risk -reduction in collaboration, and allowing for long lasting collaboration based on trust. The contracts achieve this by providing continuity, and structure in collaboration (Vlaar, 2006). Besides this function, they provide clarity in situations of conflict, and complications (Poppo & Zenger, 2002). Two perspectives on the connection between formal contracts and trust. Exist in the literature. A first perspective on the formal contracts is that they are complementary to trust (Blomqvist et al., 2005; Czernek et al., 2017). In this sense, the trust between actors leads to a contract, and the contract is a formalization of trust. Another view on contracts is the contract as a substitute of trust. Contracts are only drafted when there is no trust in the collaboration. The presence of one reduces the necessity of the other (Bachmann & Zaheer, 2006; Czernek et al., 2017). Sometimes even to the extent that the formal contracts can hamper the development of trust in the related project (Bernheim & Winstion, 1998). This shows the ambiguous interpretation of the role of the contract in theory.

Interviews

The former understanding of complementarity between formal contracts and trust, became apparent during the interviews. One interviewee mentioned that contracts are necessary to formalize the trust between actors, and to build support within the different organizations (Interview 13). Besides this, the formal contracts are needed to provide clarity in long term collaborations, which are common in energy related projects. For instance due to the basis of a 15 year SDE+ program, the collaborations are long –term, and long –term contracts need to structure these, as was stated by Interview 2. This structuring function of a contract was expressed more in the interviews. Without contracts, projects are not going anywhere. The contracts need to structure the process and specify the **business case, allocation of risks, and tasks,** as was mentioned by interviewee 2. Contracts are needed to make the standpoints of the actors clear, and provide structuring elements such as division of costs & risks, and tasks (Interview 6).

In the previous section, contracts are described as a final formalization of trust, or a final structure for the collaboration. In the process before the contracting, the **LOI/DOI** is an important first formalization of trust in the network, according to four respondents. A first division of what will be researched, the tasks, working plan, and costs & risks is made. NDA's and agreements on how to part ways when the collaboration fails could be incorporated, as was stated by Interview 6 and 15. The LOI, however, is not binding, and only works as a step in the formalization of trust, and commitment (Interview 8, 11 & 14). The intent of different actors, and agreements on the **distribution of tasks,** becomes clear in the LOI, according to interview 15. This distribution of tasks is important to prevent 'double work', and divide the workload from the beginning (Interview 3).

In between the **LOI/DOI,** and the signing of the formal contract, a second LOI, or Collaboration Agreement can be necessary, based on new developments in between the two documents (Interview 2 & 6). The decision to draft a second LOI, or CA is project specific, and will be included as a finding in the NRL.

Given the above description of formal contracts in both theory, and interviews, the contract functions as a formalization of trust, and provides necessary structure. The LOI is a first step in this process, not binding the actors, but displaying intent and a first formalization of trust. The LOI, therefore, is drafted first in NRL 3. The LOI is expected to be signed in NRL 4, since first negotiations and the development of trust in the network have taken place. The contract is expected to follow the LOI, and is drafted in NRL 5. In NRL 6, the contract is expected to be signed, based on a final formalization of trust, and the agreements in the network. From this point on the actual creation of output in the network starts.

Central Coordinating Actor

Theory

The **central coordinating actor** was mentioned by 7 out of 14 respondents as being an important property of collaboration. The role of the central coordinating actor is pulling all the actors together, and leverage the resources and skills of the different network members(Koppenjan & Klijn, 2004). In addition, his actions should lead to a favourable outcome of the collaboration (Ferraro & Iovanella, 2015; Levén, Holmström, & Mathiassen, 2014). He should pursue this by setting a common goal of collaboration, and directing all the actors towards this common goal (Arla, 2004).

The central coordinating actor could be someone from within the network, a player, or someone from outside the network, a non -player. The latter type can be further divided into sponsors of the collaboration, actors who persuade individual goals, or facilitators, actors only interested in the functioning of the network(Pikkarainen et al., 2017). Hence, the central coordinating actor in a network is an internal, or external actor pulling the project, and facilitating the collaboration. He does this by leveraging resources, and skills to work towards a common goal.

I**nterviews**

The importance of the central coordinating actor was also stressed during the interviews. The **central coordinating actor** cannot be missed, because he makes the project clear, and known to all actors. He is there to align different actors' interests, mentioned by Interview 9. By aligning the interests the central coordinating actor is able to keep all actors together in the project, and mediate when this is needed.

The **central coordinating actor** should be the person, or organization that is in charge of pulling the whole project forward. Ways to do this, were proposed by interview 6, who stated that organizing steering committees, and work groups including all actors in the network, could contribute, besides making clear agreements on communication methods, and frequency of meetings.

Installing a central coordinating actor alone; however, is not enough for successful collaboration. The central coordinating actor can function as an activator in the whole project, but when actors are not committed, or willing to work towards goals, the central coordinating actor is not enough, according to interview 8. In order to create the commitment, **the management, or key actors need to be fully committed** first. When there is doubt among them, you give criticizers the opportunity to criticize the project, which should be avoided (Interview 5 & 8). By showing commitment, the management, or key actors have the leverage to push the projects through, and avoid doubt. Support by the management, or key actors includes the **authorization** to sign LOI/DOI, and contracts in the project (Interview 15).

Consensus among the respondents on who should take the **role of central coordinating actor** is absent, since this depends on the scale and background of the project. The central coordinating actor could be an actor working on the project inside the organization, like a project manager, or someone that is appointed to function in between organizations, as was stated by interview 8. Some examples were mentioned for clarification. In the collaboration on Wind Park Ferrum, both companies provided an actor, handling the project together, aligning internal and external actors (Interviewee 3, 5 & 8). In the case of the DH –network in IJmond region, the OD IJmond takes the role of central coordinating actor, connecting the actors, trying to facilitate the collaboration (Interview 6, 9 &14).

When the projects become too complicated, since too many actors are involved, or the interests are too far apart, an *outside actor* can be appointed to orchestrate the network (Interview 9, 10 & 14). This is what happened in the bigger Warmte -Koude project on DH -networks in the MRA. An external 'regisseur' was appointed by the MRA, connecting all actors, and facilitating the collaboration (Interview 1 & 6). He was a central external actor. This prevents the idea of bias during projects, and provided a point of contact, as was stated by Interview 6 &. 9. In a collaboration between public and private parties, the governmental organization could function as this *unbiased actor***,** representing the public interest, as proposed by Interview 12 & 14. As was shown, the external coordinating actor is useful to align actors, but the external coordinating actor also means extra budget in the project. According to interview 6, the extra costs need to be shared over all actors in the network, which should be agreed upon in the LOI.

To summarize, the **central coordinating actor** plays an important role in aligning a collaboration, and keeping all actors together. Based on the literature, and the interviews, the image emerges of a central coordinating actor that cannot be missed during a collaboration in a network, because he steers the network towards a goal. After the first meetings between the actors, the central coordinating actor should be appointed in NRL 3, trying to align the actors, and steer the further network development. The actors could agree upon who takes the role of the CCA in the meetings in NRL 2. The central coordinating actor alone is not enough, and **commitment, and management support** is needed in the project.

The commitment of the management needs to be present in NRL 3, to motivate and support the project from a beginning stage. By a committed management, or key actors, the **authorization** to sign the LOI in NRL 4 is expected to be present. This authorization again needs to be present in NRL 5 to sign the contract of the collaboration.

Shared Vision

Theory

Shared vision among the actors in the network was mentioned by 10 out of 14 respondents as a property of collaboration. The exchange of knowledge, and resources between actors can only occur when shared vision is present, since the different actors need to be able to relate to the other actors' culture, and system. This is portrayed by an actors' vision (Li, 2005). A shared vision can emerge based on shared values, and mutual goals, but is not present from the beginning of the collaboration (Morgan, Hunt, Morgan, & Hunt, 2014). The shared goals cause mutual understanding and thereby an incentive to collaborate (Napahiet & Ghosal, 2018). This shows the need to create a shared vision among the actors to create an incentive to collaborate further.

Interviews

In the interviews, different opinions on the value of shared vision, and how to create shared vision emerged. A **shared vision** is one of the starting points of collaboration, according to interview 6 & 7. It is, however, something that needs to be created among the actors, and is not present from the beginning. Creating this vision is the most difficult thing in a collaboration, due to different interests, as was stressed by Interviewee 8. Different interviews (Interview 5, 9 & 10), proposed the creation of a shared vision by tuning images and perceptions of the different actors, which can be done by creating a **mutual goal** in the collaboration. This mutual goal was present in the solar panel project, because both Tata Steel, and the other actors were aiming for a green image by engaging in the project. By sharing the goal, the shared vision for the project emerged, as was mentioned by Interview 15.

A first option to create a shared vision is by bringing all actors together, and trying to align their **images of the project** (Interview 10). This must happen in the beginning stages of the collaboration, because a collaboration will develop further on the existence of a **shared vision.** As an example, the permitting procedure of a wind turbine, could be used, since the opportunity to share interests, and ideas is given to all actors (Interview 7 & 10). Giving the actors this opportunity early on, should prevent the emergence of conflicting interests later, and create a shared vision from the beginning.

It can be concluded that by creating a **shared vision**, an incentive to collaborate is given, and an understanding of what the final image of the project is. By having the same final goal in mind, the different actors' visions can be aligned. Creating a shared vision should be one of the first actions in a collaboration in order to create the basis of the collaboration. Therefore, the shared vision grows in NRL 2, because of the partner selection, and meetings taking place. The signing of the LOI in NRL 4 is seen as the first formalization of a shared vision.

Trust

Theory

Trust among the actors is mentioned by 13 out of 14 respondents as an important property of collaboration. Trust in collaboration is a belief about an actor, which results from the actors expertise, reliability, and intentionality in a project (Moorman, Deshpande, & Zaltman, 1993). Besides this, trust is the belief that the other actors will perform actions with a positive outcome, and they will not take unexpected actions resulting in negative outcomes(Anderson & Narus, 2016; Vangen & Huxham, 2003). This can be further explained with the following statement: 'Trust is the ability to form expectations about aims and the partners' future behavior in relation to these aims'. Expectations need to be formed, and fulfilled to be able to talk about trust (Ranjay Gulati, 1998; Rousseau, Sitkin, Burt, & Camerer, 1998; Vangen & Huxham, 2003). It is important that an understanding of the other actors' expectations develops in the earlier stages of the collaboration(R. Gulati, 1995; Vangen & Huxham, 2003). Actors should meet, and discuss their expectations of the collaboration. Trust is thereby an enabling condition for the formation of a network, but is sometimes even treated as a precondition of collaboration (Cullen, Johnson, & Sakano, 2000; Nielsen, 2004).

The ability to form expectations on other actors is based on **historical achievements** (Vangen & Huxham, 2003), hence trust is expected to be present in the collaboration because of historical success (Das & Ten, 1998; Vangen & Huxham, 2003), or should grow over time based on encounters with other actors (Nielsen, 2004). Antecedents on which trust is based are; **benevolence, ability, and integrity** of the actors(Davis, Mayer, Davis, & Schoorman, 1995). In other words, the trust grows based on actions, but more on willingness of the actor. Summarizing, **trust** is considered as an important factor during collaboration, or even a pre -condition of collaboration that exists based on historical collaboration, or grows based on the expectations about aims, and the behavior related to these aims.

Interviews

The necessity of trust in collaboration is confirmed by respondents in the interviews, in which the findings in theory was nearly repeated. Trust is considered as a pre -condition of collaboration, because without trust, there is not even a start to a collaboration, stated by three respondents (Interview 6, 8 & 15). Trust can be present from the beginning of the cooperation, due to long existing relations (Interview 7 & 13), or it grows due to actions of other actors in the collaboration. For the latter case, being clear about your goals in collaboration gains trust (Interview 10 &14). This is related to being **transparent** during the cooperation, and the creation of a **shared vision** based on mutual goals. Three respondents stated that sharing information, and being open about your strategy during cooperation, gains trust. Stated the other way around, the absence of trust causes actors to **withhold information**, or stimulates actors not to put all cards on the table. When there is no trust in the network, there is no actor that will hide nothing, because all actors are cautious, and waiting for other actors to take the risks. This is not how a collaboration should be build up (Interview 8 & 12).

It can be concluded based on the theory, and interviews, that trust among the actors is a necessity of collaboration, or even a pre –condition of collaboration. Trust is based on historical achievements, or actions during current collaboration. Based on the historical achievements between actors, historic trust is expected to be present in a network in NRL 1. The historic trust could be present, however, trust in the current network needs to grow along the collaboration, based on actions in the current network. The trust is expected to grow in NRL2, due to negotiations, and interactions between the actors. The trust is formalized in NRL 4 for the first time by the LOI, and later in the contract in NRL 6. The contract is a complement of trust, and not a substitute (see Appendix E.1: Formal Contracts).

Transparency

Theory

Transparency in the collaboration is stated by 9 out of 14 respondents as a property of collaboration. Transparency shown by different actors in the network leads to more trust (Nielsen, 2004). This is partly because by acting transparently, the suspicion of opportunistic behaviour is eliminated. It is this fear that is causing trust in other actors to deteriorate. Opportunistic behaviour in a network means acting to achieve own gain, without having the shared goal of the network in mind (Ring & van de Ven, 1992). This shows the connection between trust, and transparency among actors in the literature.

Interviews

The results of the interviews showed a clear connection between transparency, trust, and the importance of transparency in a collaboration. Like trust, it is has been stated as a pre -condition of collaboration.in interview 6. Transparency of actors on; problems, challenges but also motivations, and goals will help in a collaboration. It shows commitment, and an insight into the interests of the actor involved (Interview 10). **Transparency** is connected to **trust,** since being open about plans, and possibilities, creates trust in a collaboration, as was mentioned by four respondents. Being transparent shows the real intent of actors in the network. Transparency prevents the existence of hidden agendas and other interests than the output of the collaboration (Interview 10 & 15).

In the solar panel case, the sharing of calculations on the business case, was transparent, and caused trust. Being open about the division of cash flows, and profit functioned as a good starting point for further collaboration, and provided an open playing field (Interview 8 & 11). In the same project, the transparency disappeared after first doubts on the profitability of the project, and thereby the trust in the project. The fear of a hidden agenda, and different interests emerged, according to interview 11 & 15.

Given the above insights from theory, and interviews, **transparency** displayed by actors in a collaboration not only creates **trust**, but also prevents the idea of opportunistic behaviour, hidden agendas, and other interests in agents. When actors are transparent, their real intentions are present, creating a basis of collaboration. Transparency is thereby a pre-condition of collaboration. Transparency needs to be shown by sharing all potential relevant knowledge in the network, thus it is expected to be displayed in NRL2, when the trust grows, and the shared vision in the network emerges. All information, by being transparent should be known in NRL 4, when the LOI is signed.

Reliability

Theory

The **reliability** of actors was mentioned by 7 out of 14 respondents as a property of collaboration. Reliability is determined by Weick as the: 'Continuous re-accomplishment of near failure-free performance in dynamic environments (E. Weick, 2011). The actor shows reliability by performance during the collaboration. The reliability of an actor can be displayed by both actions anticipating an unexpected event, and managing unexpected events during the collaboration (Rantatalo, 2012). The reliability of an actor is thereby different from trust. Being reliable is related to performance during the collaboration, whereas the trust is related to the social aspects, and the expectations of the actors before the collaboration, as can be seen in the interpretation of the property of trust.

Interview

In the interviews, the reliability of actors is based on previous collaboration, and the reliability in the current project. The selection of a partner to execute a project with, is based on performance in earlier projects, because it shows the competence of the actor. This is the **historical reliability.** Showing a high level of skill, and knowledge causes the reliability of an actor to grow, as was mentioned by actor 3. Failure to deliver, and holding back information during the current project reduces the reliability (Interview 11 & 14). The reliability of the actor is dependent on delivering what is promised, and on anticipating to unexpected events. The reliability during the project is considered the performance **reliability.**

In the Solar Energy project, unexpected negative effects were treated as problems. Instead of anticipating to them, and containing the unexpected events by finding adequate solutions. Difficulties in finding financing for the project, and a diminishing electricity price, leading to a lower ROI were factors which could not be contained, but could seriously threaten the outcome of the project. Non –adequate dealing with these unexpected events lead to a decrease in the **reliability** of the actors concerned in the project. On the contrary, in the project on Wind Park Ferrum, unexpected safety concerns came up, regarding the critical areas of the wind turbine blades, and the potential of hitting critical buildings, if a blade would fall off the turbine. These concerns were solved with adequate solutions by all actors concerned, which was well received, and lead to an increase in the reliability (Interview 15). The actors had a problem solving attitude which caused the reliability to grow during the project (Interview 3, 8 & 15).

As can be seen from the theory, and interviews, the reliability is strongly related to trust, but more dependent on the performance of the actors. It is divided into the historical reliability based on previous collaborations, and performance reliability based on actions in the current collaboration. The historic reliability is expected to be present in NRL 2, because actors meet in negotiations. However, the historic reliability only exists when the same actors meet in a new collaboration. The performance reliability is dependent on the actions during the collaboration. The performance reliability will become present after the first steps in the network development. Actors must have shown by their actions that they are reliable in the network. Therefore, the performance reliability is expected to be present in NRL 3, based on the first performance of actors in the network.

Concluding Remarks Properties

A total of six properties of collaboration were discussed in the previous paragraphs. Based on this discussion, two important conclusions can be drawn. At first, the properties of trust, reliability, transparency, and shared vision were mentioned as factors that could not be missed during the development of a network. Therefore, they are considered as pre **-conditions of collaboration.** If one of these properties is missing in the network, the collaboration does not happen. Efforts need to be put into the network by different actors in order to achieve the three pre -conditions of collaboration. These soft variables are key to the socio –technical system, as can be drawn from the different answers of respondents. Therefore, these four properties are included in the draft of the further NRL.

A second conclusion based on the outcomes is the notion that properties of collaboration can be divided into **process, and product variables**. The process variables are the soft variables of; trust, reliability, transparency, shared vision, needed during the collaboration, whereas the product variables are the physical products of collaboration in the form of; a central coordinating actor, formal contracts, and signed LOI. These products are needed to structure the outcome of the collaboration, by formalizing trust, and providing clarity on tasks. This distinction between process, and product is important in structuring the draft of the NRL, and will be included in the NRL

E.2 Facilitators

The facilitators of collaboration are presented by mentioning the coding classes that were used during the sorting exercise first. After, the specific facilitators that were selected based on the outcome of the sorting exercise are discussed. Specific facilitators that came up as remarks by the respondents are presented in **bold.**

Collaboration

Willingness to share resources and knowledge

Theory

The **willingness to share resources and knowledge** in a collaboration is partly dependent on the amount of **trust** experienced between different actors (Napahiet & Ghosal, 2018). When experiencing trust, knowledge sharing becomes easier, since the suspicion of opportunistic behaviour is absent(Ring & van de Ven, 1992). Sharing knowledge is further influenced by individual motivation to share knowledge, the value of knowledge shared, reciprocity (do we get something back for sharing knowledge), and the reward(what do we get back) that is perceived when sharing knowledge (Ipe, 2003; Ramim & Lichvar, 2013). This shows that sharing knowledge is both influenced by trust, and the perceived profit of sharing knowledge. When the notion is created that sharing of knowledge increases the value of knowledge in a network, since it is shared among others, the sharing contributes to the final goals and shared interests of the actors (Ramim & Lichvar, 2013).

Interviews

The **willingness to share resources and knowledge** was mentioned by 12 out of 14 respondents as a facilitator of collaboration. This facilitator is connected to trust, shared vision and transparency. The three properties cause the willingness to share resources and knowledge to grow, as was stated by interview 12. Sharing knowledge creates the situation in which all the knowledge is present in the network, and multiple actors could benefit from this. It creates transparency, and shows that different actors are not 'keeping their cards closed', as was stated by interview 2 & 12). A way to stimulate this, is by **becoming familiar with the background of the actors**, and their supporters (Interview 12). This creates a working environment in which the actors in the network not only understand what is driving, or sometimes hindering the collaboration, but also how actors are limited in their possibilities.

Another way to facilitate the willingness to share resources, is by **creating the image of a 'must have' technology, or project,** instead of a 'nice to have' one (Interview 9 & 15). The necessity of sharing knowledge, and resources becomes clearer based on this image. An example is the development of the DH- network. If the actors are aware of each other's backgrounds, and share the image of a 'must have' technology, an incentive is created to share knowledge (Interview 12).

To summarize, the sharing of knowledge, and resources becomes easier with trust, knowledge of the background of actors, and the image of a 'must have' project. Two facilitators are therefore included in the NRL; the **knowledge of actors' background**, and the **image of a 'must have' project.** In NRL 2, the knowledge of the actors' background needs to develop, based on actor meetings during this phase of the network development. Besides the background knowledge, a 'must have' image is a potential facilitator in NRL 2 that should encourage different actors to continue the collaboration. The actual willingness to share knowledge and resources is facilitator in NRL 3, since the actors are together in the network, have to express their intent, and make agreements on the further steps of the collaboration.

Well -established relationships

Theory

The presence of well -established relations at the beginning of the collaboration is not connected to findings in theory. The facilitator is a general idea of relations in a network based on previous encounters, and is therefore case specific, and not connected to theory. Besides, this the description is too general to be connected to theory.

Interviews

A second important facilitator is **well -established relationships** present at the beginning of the collaboration, mentioned by 6 out of 14 respondents. Having a relation already based on a previous encounters, causes actors to share knowledge, resources, and to support the same vision from the beginning of the project, due to existing trust, and experience. As was stressed by interview 7 & 13. The relationships are a good start to the collaboration, and make sure a common goal is found easily (Interview 6). These relationship; however, are not always present, since new collaborations are entered into. Therefore, **good partner selection** is a facilitator in collaboration, as was stated in three interviews (Interview 3, 4 & 15). **Criteria for the partner** selection have to be drawn up when network creation takes place (Interview 1 & 3). Both financial considerations, and more collaboration related (soft) criteria need to be included, such as experience, reliability, and a fit to the project (Interview 3). These criteria were set -up for the selection of the partners in the Wind Park Ferrum case, and although the selection was fast, and under time pressure, the criteria posed a guideline for the process, with a positive impact on the successful collaboration as a result (Interview 3).

The selection of partners is not related to the actors involved in the network based on network emergence. For network emergence, it is important to **involve all actors**. This should be done by giving all actors, potentially involved in the network, a possibility to participate (Interview 7, 8 & 15). In the Wind Park Ferrum project, Tata Steel invited a local interest group to join negotiations from early on in the project. In order for them to understand what was going on, and provide input. Besides this, the local residents could participate in the wind park, in buying shares. This was received well, and a facilitator of the later collaboration (Interview 7).

To conclude, the presence of **well -established relations** is a facilitator of collaboration, because it makes the sharing of knowledge and resources easier, and trust exists. The relations are, however, not present in many cases, therefore **good partner selection,** is needed. The partner selection needs to be structured by selection criteria. Selection takes place in the beginning of the network, in NRL 2, since the first meetings about the collaboration are taking place, and trust, shared vision, and transparency grows in the network. Besides partner selection, all actors need to be involved in the network at NRL 2, to prevent problems later on because actors are left out, and to give all potential actors the possibility to collaborate.

Alignment of Interests

Theory

The **alignment of interest** is a process in which the actors of the network try to overcome resistance, due to conflicting interest, and stabilize the network (Ponti, 2010). Furthermore, the alignment of interests is again important in the trust building process of the network (Zuppa & Issal, 2008). Aligning interests, causes trust among the actors, since same values are shared. A key factor to achieve aligned interests, is the knowledge of how to communicate effectively, to make interests, and actors' values clear (Reed, 2001). When the interests of actors are expressed well, the aligning of the interests becomes easier. Aligned interests of the actors in the network shows shared vision, and values in the network, thus working towards a greater goal of collaboration. This greater goal is called the; **collaborative interest**, by Zuppa (Zuppa & Issal, 2008). If the greater goal is understood, the actors know of each other what their interests are, but that the collaborative interests is the most important.

Interviews

The **alignment of interests** among actors was mentioned by 11 out of 14 respondents as a facilitator of collaboration. The alignment of interests is a facilitator of collaboration if the idea arises that the interests might be contradicting, but that working together contributes to a greater goal. In aligning the interests, as a first step, the personal interests of the actors should be understood by other actors, as was mentioned by interview 8 & 9.

A second step in aligning the interests is the **change of mind-set** from: 'I need this, you have to understand this, to: 'What do you need and how do we get there?', as was mentioned by interview 12. By changing the mind-set, a **greater goal** within the network is pursued. This second step starts with the willingness to understand others' standpoints, and look for solutions, instead of opposing the collaboration with own interests (Interview 10). A final, third step is the actual search of where actors can help, or supplement each -other. Interests could be contradicting, but actors should find each – other on the compensating plane, proposed by interview 7.

One way to create the mind -set to translate the interest is by **creating the same image** of the final project in all actors. This is not the same as the shared vision among the actors on the collaboration, but is focussed on the final product of the collaboration. If this is clear, the larger goal of the collaboration will be easier pursued, due to the mutually shared image (Interview 9 & 10). An example is the idea of contributing to a more sustainable society by developing a DH -network, not only looking a financial gain (Interview 6). Another example is working together with other actors on Wind Park Ferrum, or the installation of solar panels, not necessarily for financial gain, but to contribute to the energy transition in all possible ways (Interview 5). Once the final image of installing solar panels, and building a wind park is present in all actors, at least the different interests are not threatening the development of the project anymore (Interview 5 & 11).

To conclude, the effort of trying to align the interests of actors is important in a collaboration. The alignment of interest exists when the **interests of the actors** are understood by other actors, the **mind –set is changed** towards a greater goal of the collaboration in NRL 3, and **the same image** of the collaboration is created. The aligned interests are therefore the result of the first interactions between actors in the network, however, aligning of the interests takes time, due to actor meetings and the creation of shared ideas. The interests are expected to become aligned by the emergence of a shared final image among the actors in NRL 2, the knowledge of the background of other actors in the network in NRL 2, and the change of mind- set by of actors in NRL 3. As a results, the interests are expected to be aligned in NRL 4.

Set Targets and Goals

Theory

The facilitator of set target and goals is not connected to the theory, due to the general notion of targets and goals. Targets and goals are expected to structure a project, but are not further explained based on findings in theory.

Interviews

The setting of **targets and goals** for the collaboration was mentioned by 4 of 14 respondents as a facilitator of collaboration. Targets and goals need to be set, to work towards something in the collaboration, since they provide firmness in the process. Goals are, however, expected to be present, and are part of a project, as was stated by three interviews (Interview 7, 8 & 10). You need to have a 'dot on the horizon' to work towards in a collaboration to know why you are working together (Interview 2). Whether this is a reduction target, or a date at which a wind park must be established, does not matter, but the final target needs to be clear, according to interview 3.

A distinction should be made between the networks' own goals, drawn up by the actors, as discussed above, and the targets and goals set by governments, or other regulatory authorities. The latter goals are working as a steering mechanism, and the final goal of the collaboration contributes to these governmental goals, as mentioned by interview 14. A goal to phase out natural gas, reduce CO_2 emissions in industry, and the introduction of regional energy strategies functions as a good general starting point. It is the role of the networks to contribute to this with their own goals (Interview 14).

Concluding, the targets and goals set in a collaboration are there to structure the process, and to work towards a clear end. They provide clarity, and firmness in the process of collaboration. The targets are determined during the collaboration, and will not be present from the beginning. The targets are a result of the meetings, and are proposed in the LOI in NRL 4. The targets are, therefore, expected to be present in NRL 4.

Political (Regulatory & Institutional)

Support by Decision Makers

Theory

The support by decision makers is not connected to theory, due to the broad understanding of the term. The insights of the interview results should provide the idea of the support by decision makers on the network.

Interviews

The **support by decision makers** was mentioned by 10 out of 14 respondents as a facilitator of collaboration. The support by decision makers is relevant due to the collaboration between public, and private actors in the cases studied. If a local councilman, or the local policy is firmly against the development of a DH –network. Starting a project on a DH -infrastructure in the region is hard, since it is swimming against the tide (Interview 9). In the example of the DH -network, the local OD- IJmond, started the project, connected different actors, and still facilitates the project, which shows that support by the local authorities is present. The **commitment, and goal** of the local decision makers triggers a project in this case, as was stated by interview 6 & 9. This only shows an example on the lower level, but also on the higher levels, the support by decision makers is needed.

The higher provincial decree on wind turbines on land, caused an incentive to develop Wind Park Ferrum, because it gave the possibility to search for potential locations (Interview 1 & 5). By presenting rules, and guidelines; **a boundary, and scope** of the project was created. The decree created a framework for the development of the wind park, as was stated by interview 8. The support by decision makers, thereby creates the conditions under which the project is conducted.

Besides providing an incentive, and a framework, the support by decision could **facilitate** a collaboration. In the DH -network, the OD IJmond has a **facilitating** role, and connects different actors, whereas in Windpark Ferrum, the OD NZKG was leading in the authorization procedure (Interview 3 & 10). The support of decision makers in this case finally leads to the issuing of **permits** for constructing the project (Interview 10).

The final remark on the support by decision makers is on the importance of multi –level collaboration, which was mentioned by 5 out of 14 respondents as a property of collaboration[23]. The support by decision makers has to come over the different levels of policy; national, regional, local. The national government could facilitate the development of DH –networks by introducing clear laws on the heat market, and the costs of infrastructure and heat (Interview 6 & 9). On the other hand, the Province could facilitate the development of DH –network by monitoring the development, and acting as an institute of knowledge (Interview 12). Finally, a local councilman being an advocate of a DH –network in his municipality could facilitate the development by actively promoting the development of the network, and bringing the actors together (Interview 14). This shows the importance of the support by decision makers over different scales of policy.

[23] The property was mentioned by 5 out of 14 respondents, but was left out of the scope, because the understanding of 'multi –level collaboration' was too diverse among the respondents. The property is discussed in this section to show the importance of multi –level support.

Based on the above, the support by decision makers causes a trigger to collaborate, but more importantly creates a framework in which the network can operate. The support by decision makers can function as an incentive to start a collaboration in NRL 1 (see Appendix G). However, the support by decision makers could also exist in a facilitating role, due to the decision maker acting as a facilitator in the project. The facilitating role could be present in NRL 3, with the decision maker functioning as a central coordinating actor. The final result of this support leads to a permit for constructing, which has to be present in NRL 6. The support by decision makers could also create the boundary, and scope of the collaboration by creating the conditions of the collaboration, the support by decision makers functions as a facilitator in NRL 3 in that case, since the impact of the decision makers on the project should be known by then.

Economic

Financial Gain

Theory

Financial gain in the project is presented as a general term, and is therefore not connected to theory. Based on the outcomes the interviews, the meaning of financial gain for the different actors will become present.

Interviews

An economic basis to a collaboration is always the most important facilitator, according to some respondents. There is no need to start a project, if a positive business case is absent (Interview 1, 6 & 9). There are, however, different explanations given by the respondents regarding this **economic basis.** It is not necessarily related to the **financial gain** coming from an investment, but could also exist in the **value chain** of the project, **the sharing of risks, the sustainability improvements**, or **CO2 reductions**, thereby the idea of financial gain changes into the gains of the project.

Financial gain is not the always the most important, a positive **value chain of a project** could be a different facilitator. The value chain of the project should provide a profit over the whole chain of improvements, and actors: cost reduction, return on investments, maintenance, process improvements. If this is clear, one could talk of financial gain (Interview 2). This value chain is not created by only one actor, but could exist over multiple actors in the network, all bearing profit, but also risk along the value chain. The **financial risks** in the value chain need to be bearable for all actors. An unequal distribution of risks lead to disturbed relationships in the network (Interview 2, 6 & 8). On the other hand, the fair sharing of risks leads to better collaboration, and shared interests (Interview 6).

Another interpretation of the financial gain is the **sustainable profit** that is achieved. By building a wind park, or constructing solar panels, a sustainability component is present. The projects add to society, and make their profit in sustainability, as stated by interview 8. The business case of the Windpark Ferrum was not the most important factor in the development, this was the **sustainable profit, and green image** of the project (Interview 8). The same holds for the Solar Panels on the roofs, which have green image, and sustainability motivation from the Tata Steel side. This is different from the investors' point of view, but the common goal of the project would have been a green image, and the PR value, as was mentioned by interview 15. A remark should be made on the fact that renewable energy projects are still dependent on the **presence of subsidy**. Even though the SDE+ subsidy was granted for both the solar energy, and wind energy projects, the financial margin of the project is small, as was stated by five respondents. The availability of subsidy is thereby a facilitator in the project. The subsidy is needed to buffer the fluctuations in the energy price, and generate a steady ROI (Interview 3 & 8).

Process improvement, **cost reduction,** and **reduction of CO2 emissions** could also cause financial gains, as is proposed by interview 2. An example of this is the development of the DH -network, and the allocation of CO2 certificates. Besides a price for the heat that is delivered by Tata Steel, a potential gain could be the allocation of CO2 certificates. The heat delivered by Tata Steel makes the society a little more sustainable, and the reduction of CO2 should be accounted to the heat delivered by Tata Steel, as was proposed by interview 6 & 14. This not the case yet, but would be a potential, not directly financial gain of the DH -infrastructure (Interview 2).

To conclude, the financial gain of the collaboration is a facilitator of the collaboration, because a positive business case is needed in the project. The financial outline of the project should be known in NRL 4, when he actors show their intent in the project. This means that an idea of the potential value of the project is present, but further calculations need be done. The idea gives an incentive to collaborate further. In NRL 5, the research on the feasibility of the project takes place. The business case of the project is, therefore, expected to be clear in NRL 5. Besides, a positive business case, different other ideas on the gains of the project were expressed during the interviews. The gain is therefore, not only related to financial gain, but also **the value chain of the project, the sustainable profit, green image, and allocation of the CO2 reduction.** The idea of gain in the project is expected to be present in NRL 5, together with business case of the project. A final idea of the gain of the project for all actors is present in the NRL 6, together with the signing of the contract.

Technology & Geography

The coding classes of **technology** and geography were present in the sorting exercise, but are not further discussed. This is due to the fact that technology is considered available, according to four respondents. The discussed networks are collaborating for the implementation of existing technologies, and not for developing a new technology, or creating innovation output. Therefore, the availability of technology is not considered a facilitator of collaboration, but something that is present. Like interview 2 mentioned, the technology is not a problem in the collaboration. Technology wise we will find a solution. This was further emphasized by interview 6, who stated that the technology is far less of a facilitator than a positive business case, or collaboration factors in the network.

The same holds for the **geography** as facilitator of collaboration. Geographic proximity, or a small network was not considered a facilitator of collaboration. Only the local actors, such as the local environmental interests organization, and the local municipality, considered the geographic proximity important, since they were only concerned with local affairs. It would not make sense to engage in projects taking place in another part of the country, as interview 7 & 14, stated. They considered this fact, however, given and did not see the proximity of actors facilitating, just something that was considered to be present.

Concluding Remarks Facilitators

In the previous sections, the facilitators of collaboration are discussed based on the different coding classes. The most important facilitators of collaboration came forward from the **collaboration** coding class. The willingness to share resources and knowledge (12 out of 14 respondents), creating the same final image, and becoming familiar with the background of others were considered facilitators of collaboration. From **communication,** the alignment of interests by creating the same final image, came forward as a facilitator of collaboration. The support by decision makers was mentioned by 10 out of 14 respondents as facilitator of collaboration, since the support could provide the incentive, and facilitate the collaboration by creating the conditions in which the network collaborates. The support by decision makers steers, and helps in the further development of the network. The **political factors** create a framework for collaboration. In the **economic & financial** coding class; financial gain, sustainable profit, positive value chain, were all mentioned as facilitators of collaboration. If the financial part of the network is not positive, there is no need for collaboration at all. The presence of **technology** was not mentioned by any respondent as a facilitator of collaboration, since this is expected to be present. The same holds for the **geography** in the network.

To summarize, the soft factors coming from the collaboration and communication coding class are considered facilitators of collaboration. The economy, and political factors are the factors that create the framework of collaboration (political), or make the collaboration possible in the first place (economic).

E.3 Barriers

Collaboration

Uncertainty about the outcome

Theory

Uncertainty about the outcome of a project is connected to the **risk of the project** and the **ambiguity** regarding the solution. The uncertainty not only causes a risk, because it is not clear if the project is going to be finished, and what the financial bearings will be, but also causes ambiguity, because there is not a clear solution to solve the uncertainty (Walker, Davis, & Stevenson, 2017). The uncertainty could come forward from untapped knowledge, because the knowledge is present, however, not at the right place in the network, or from unexpected events that happen during the development of the project (Kurtz & Snowden, 2003). If uncertainty is caused by the untapped knowledge, the collaboration requires extra effort in the form meetings, or commitment to move the knowledge to the desired place (Walker et al., 2017). If the uncertainty comes from unexpected events, the actions taken by the actors refer to their reliability, since they are expected to manage the unexpected event (Rantatalo, 2012) (Appendix E.1:Reliability). As comes forward from the above description, the uncertainty of the project is related to risk. Risk can be known, is calculable, and can be predicted to some extent, whereas uncertainty cannot be known, but can be acted upon (Perminova, 2011). When the uncertainty is not acted upon, it can be a barrier to the collaboration.

Interviews

Uncertainty about the outcome of the project was mentioned by 5 out of 14 respondents as a barrier of collaboration. This uncertainty emerges due to various reasons. At first, due to the fact that **not all information is present** in the project. This causes the perception of a bigger risk in the execution of the project to be present, according to interview 3. For example, the precise wind speeds at the location of the wind park were not known during the project, which caused uncertainty about the final profitability of the wind park. The uncertainty thereby caused an investment risk, because the total value of business case was not known. The same happened when the electricity prices in the solar panel case declined, causing an uncertainty in the profitability of the solar panel project, and a higher investment risk (Interview 4, 8 & 11). As a second reason, the fact that **key actors are leaving the process,** leads to a delay in the actions, and a loss of specific knowledge in the network, causing uncertainty about the outcome (Interview 10 & 12). These uncertainties potentially cause barriers in the project.

Besides the above mentioned uncertainties, the **regulatory uncertainty**, causes uncertainty in investments, and development of DH –networks. Actors are cautious when investing, which is further discussed in sub -paragraph 2.3.3.1. Besides this, **long -term procedures** cause uncertainty about the outcome to arise. Three interviews (Interview 11, 13 & 15) stated that long processes were present in the solar panel case, due to long negotiations, and very juridical determination of the risks, and responsibilities. This is beneficial for the risk reduction, but was negative for the flow of the project, causing uncertainty about the outcome (Interview 11, 13 & 15). These long -term contract negotiations are related to the collaboration becoming **more juridical** along the process, by formal contracts, and legal departments of the actors working on formal agreements.

This should provide certainty, and clarity about the project, but at the same time causes actors to lose track, and attention to fade away (Interview 11 & 13). Eventually leading to a loss of commitment, or involvement, as was stated by interview 15.

Potential solutions to reduce risk, but at the same time prevent long – lasting procedures were mentioned during the interviews. A potential solutions was to agree in the LOI, or contract on new negotiations once a potential risk had occurred. This should prevent long -term contract negotiations (Interview 11 & 15). Another solution was proposed by interview 15 on the long term negotiations in the solar panel project. He proposed the start of the project on a small scale, that was not risky, and uncertain, and increase the size of the project once the risks were all dealt with in the contract negotiations. Starting already would give the project a kick -start, and prevent failure due to long -term negotiations.

To conclude, the uncertainty about the outcome is caused by both unexpected, and expected/known events. The unexpected events; **not all information is present, and key actors leaving the process**, need management, as was presented in the literature. The information not being present in the project is a barrier that could occur along all levels of the NRL, because new information could be needed at different moments in time. The NRL 6 is chosen for the barrier to occur, since all the information needs to be present to sign the final contracts of the collaboration. A remark, however, must be made on the fact that the barrier could occur in different phases, based on the willingness to share information among the network actors. The same holds for the key actors leaving the process, since this could happen along the development. The leaving of actors becomes a barrier in NRL 5, because the LOI is drafted in NRL 4, and actors leaving the process after this leads to a new NRL –draft. The expected events; **regulatory uncertainty, long -term procedures,** and **juridical procedures** need anticipation, according to literature. The long –term procedures occur due to the long lasting contract negotiations, and the disagreements emerging during these talks. The long –term procedures are, therefore, expected to become a barrier in NRL 5. Regulatory uncertainty is expected to become a barrier earlier in the project, in NRL 4, because the actors share an intent at that point in time (LOI). Uncertainty on rules & regulations causes a barrier in the further research on executing the intent of the collaboration, taking place in NRL 5.

Knowledge Sharing is Difficult

Theory

Knowledge sharing between different actors within the same firm, but more importantly within the network, should change individual knowledge into network knowledge (Chow & Chan, 2008). The first type of knowledge sharing; within the same firm, is dependent on the volition of the actor, and leadership. Top management can support the sharing of knowledge by sustaining knowledge exchange through formal authority, and executive involvement, thereby creating pressure on the sharer of the knowledge (Yang & Maxwell, 2011). Sharing knowledge between actors in the network is based on; extrinsic rewards (the value of the knowledge), reciprocal relationship, and the climate that is encouraging the sharing of knowledge (Chow & Chan, 2008). Long – term relationships have an encouraging role in the sharing of knowledge (Saghafi, Mohammad, Mirsarraf, Kary, & Abadi, 2012). In these long -term relationship, **trust** is embedded, which is a catalyst facilitating knowledge sharing (Chen, Lin, & Yen, 2014; Morgan et al., 2014)**.** The amount of shared knowledge is determined by the perceived benefits, the information exchange, and the contractual agreements between the different actors (Cheng, 2011). In the literature, the potential benefits of sharing knowledge, and the incentives to share knowledge within a network are given. The potential adverse effects of not sharing knowledge, the potential barrier of not sharing knowledge to a collaboration, are discussed based on the interview outcomes.

Interviews

The difficulty of knowledge sharing was mentioned by 5 out of 14 respondents as a barrier of collaboration. Not sharing knowledge in the network causes **incomprehension among the actors** in the network, since not all information in the network is present. This incomprehension causes difficulty in the creation of a shared vision in the network, as was mentioned by interview 7.

As an example of the value of shared of shared knowledge for a collaboration, the case of the DH -infrastructure in the IJmond region, is used. In this project, there was uncertainty about the amount of heat available from Tata Steel that could be an input in the DH -network. Different parties already laid a hold on a big amount of heat, when the exact number was not known yet (Interview 12). The statement of Tata Steel about the amount of heat available for the heat network, that followed later, was on the one hand disappointing, because there was already speculated for more (the amount was 15 MW instead of 70 MW). On the other hand, the statement provided clarity on the possibilities of the network, and helped in aligning the vision of the actors in the network, by providing the information needed (Interview 12). The sharing of information is indispensable when creating the final vision, and goal of the network. It is better to share than to wait and speculate, despite the disappointing statement on the amount of heat.

The sharing of knowledge, however, remains difficult, since actors are keeping their cards closed, because of **different interests,** and the **absence of benefits.** In the network of DH – network development, the market parties are keeping their cards closed. Information is shared occasionally, and the whole process is a little bit like ‘black box’ (Interview 12). It is not clear among the actors what their goals, and interests are in the network, because not all information is shared (Interview 9). Even when an ‘Open Innovation’ approach is used, in which all actors are asked to share the information needed, and a mutual benefit of developing a DH -infrastructure together is present, not all information is shared (Interview 14).

Another reason for not sharing information is the sensitive character of the information. The sharing of knowledge is more easily done, when non -sensitive information is shared (Interview 1 & 9). Not sharing information based on this motivation displays a lack of trust, and the absence of the bigger picture of collaboration. This could eventually lead to the suspicion of **withholding information,** causing a further deterioration of trust in the network (Interview 12).

To conclude, the sharing of information is difficult due to; the lack of trust, the potentially sensitive information, and the absence of benefits. The absence of benefits as a barrier for the collaboration will only become clear once the calculations on the business have taken place in NRL 5, leading to negative outcome... The withholding of information as barrier could already occur earlier in the process, when the actors are together for the first meetings, and the actors are not willing to share their knowledge, occurring in NRL 3. A remark should be made, however, on the fact that sharing of knowledge should happen throughout the network development. New knowledge on the project is needed in every step, and withholding of information could therefore cause a barrier in the network at any time. NRL 3 is chosen in this case, since the actors are together in the network, working towards a shared intent in the project. If knowledge is not shared at this point in time, the intent of the network cannot be executed further.

Political (Regulatory & Institutional)

Legal Constraints

Theory

In theory, different **legal constraints** as barriers of renewable energy development are mentioned. A first barrier, is the restriction on siting, and construction of renewable energy technologies due to safety, environmental, and ecological concerns. As a second barrier, the absence of a framework guiding the introduction of renewable energy is mentioned, referring to the absence of policy, subsidy, and regulations, rather than legal constraints (Beck & Martinot, 2004). This absence of a regulatory framework causes unstable and unpredictable investment environments, with the result that barriers of investment are not overcome (Painuly, 2001; Polzin, 2017). These barriers are characterized by investment risks, uncertain rules & regulations, administrative hurdles, and delayed project approvals (Nasirov, Silva, & Agostini, 2015; Polzin, 2017). The institutions on the one hand create a bounding structure for the renewable energy development by the rules & regulations regarding permits, safety and the environment. On the other hand, the absence of these rules & regulations cause uncertain investment environments, and the withholding of potential investments. The institutions, thus, have a guiding role in the development of the networks, by creating the conditions in which the networks develop. This guiding role is further discussed in the interviews.

Interviews

Legal constraints was mentioned by 6 out of 14 respondents as a barrier of collaboration. Governmental regulations are both a chance, and a barrier for collaboration. On the one hand they provide an incentive to engage in the renewable energy projects, on the other hand they function as a constraining factor, as was mentioned by interview 2. The rules of the province regarding the 6 wind turbine installation, and the 2 for 1 rule were limiting the size of Wind Park Ferrum, showing the regulations as a constraint.

Besides this, the physical appearance of the wind turbines had to be the same as the already existing wind park. This caused the choice for a wind turbine with less power (2 MW instead of 3 MW), meaning a negative incentive for the business case (Interview 3 & 8). In this example the governmental regulations are hindering the exploitation of the full potential, which can be seen as a **legal constraint.**

Contrary to the rules & regulations constraining the development of renewable energy, are the **legal uncertainties.** As was mentioned by 4 out of 14 respondents. The absence of rules & regulations leaving uncertainties regarding the development of renewable energy, and waste heat, functioning as a barrier. Interview 6 mentioned that regulations are not necessary, and developments of renewable energy projects can take place even without regulations. Hence, the development of DH -networks without clear laws, rules & regulations. The regulations, however, could function as a structure, and facilitator of the projects, that could positively influence the development of the DH -networks (Interview 6).

As an example the development of DH -networks is given, because of the absence of rules & regulations. This absence causes business cases to remain negative, DH -infrastructure to remain dependent on subsidies, and uncertainty about investment decisions (Interview 6). On top of this, the uncertainty about the direction of future policy causes actors to monitor the situation, but not fully engage in projects, causing a slow pace in the development of DH- networks (Interview 6, 9 & 12). As to one actor, a 'deadlock' exists in the market of DH -infrastructure development, because of different parties waiting for a clear indication of future policy. This leads to missed chances in DH -infrastructure development, due to prudent investments (Interview 12).

A solutions is proposed in the interviews to tackle the regulatory uncertainty regarding DH -networks. The first is to prepare for future regulations, by already mapping the possibilities for DH -networks in a region, and planning on what the first steps for DH -infrastructure development will be (Interview 12 & 14). This is actively done by the province of Noord-Holland in collaboration with the municipalities, and makes sure the actors are ready to anticipate to new rules & regulations.

The regulatory uncertainty causes a deadlock on the one hand, since there is no regulation, on the other hand it causes a free playing field for the market parties. This was further emphasized by the remark of interview 8 &13. The interviewees stated that the politics create a **level playing field, or the working conditions** for collaboration on renewable energy. The rules & regulation influence the collaboration, technological, and financial dimension of the network by providing steering, and incentives. When the level playing field is present, the development of the renewable energy projects take flight. Five years ago the regulations on solar meadows was absent, at the moment the regulation is in place, and the solar panels are installed rapidly, according to interview 6. The same holds for the development of off -shore wind parks, which was hugely stimulated by a regulatory framework (Interview 8). The absence of a clear **level playing field** for the DH -infrastructure development could therefore be seen as a barrier of the development, stated by interview 6, 9 & 14.

To conclude, legal constraints prove to be a limiting barrier to collaboration, whereas legal uncertainties lead to a wait-and-see attitude. Institutions should steer the development of renewable energy, and waste heat by providing a level playing field for collaboration. In the level playing field, the rules & regulations function as a bounding, and steering factor.

The legal uncertainties are expected to become known once all the actors are present in the network, and the LOI is signed. The intent shown in the LOI needs to be researched further in NRL 5, leading to insights on the legal uncertainty, and the absence of a level playing field of collaboration. Legal restrictions on the other hand, are expected to be known in an earlier stage of development, because of the presence of governmental actors in the projects, from the partner selection in NRL 2 onwards. Before the LOI is signed in NRL4, the legal constraints could present a barrier in the collaboration.

Economic

Disagreement on the allocation of costs and benefits

Theory

The allocation of costs and benefits in the network is not discussed based on theory, since the term is too general as a concept. Only the outcomes of the interviews are discussed.

Interviews

Disagreement on the allocation of costs & benefits was mentioned by 8 out of 14 respondents as a barrier of collaboration. The barrier is difficult to interpret, since the interests, and thereby the perceived benefits are very different in a network that exists of public, and private actors. The public parties serve the general interest, and create a contribution to society, whereas the private actors are looking to make a profit, driven by financial gains, PR, or sustainability. If the costs & benefits are not allocated well, there is **no incentive, or even a negative incentive** to engage in a project. The unequal allocation could thereby function as a barrier, according to 15. For example, if a party has already made three commitments, reducing its own financial gains of the project, and other actors are still not satisfied with the division of costs, the disagreement on the allocation of costs and benefits functions as a barrier for further collaboration (Interview 4 & 15).

In the case of the DH -heating network, the gains of CO2 emission reduction are not allocated equally. Tata Steel does not bear the benefits of making its heat available for the DH -network, because the achieved CO2 reduction does not count for the production processes. If Tata Steel, however, profits from the CO2 benefits, causes an incentive to cooperate, because of the perceived benefits (Interview 6, 12 & 14).

A different factor mentioned in allocating the costs & benefits is dividing **the costs of an external central coordinating actor**. In an ideal solutions the external actor is paid by all actors in the network equally, according to interview 6.

Finally, the allocation of **the investment costs, benefits & risks,** could cause a barrier in the collaboration. In the researched cases, Tata Steel does not invest in renewable energy projects, and the allocation is therefore not an issue, however, disagreements on costs & benefits are causing delays. In the DH -infrastructure development cases, the absence of regulations causes actors not to invest at all, because the future allocation of costs & benefit is not clear, as was mentioned by interview 12 & 14. In the solar panel case, a disagreement on the profit percentage, costs for the rent of the roofs, and the minimal electricity price paid by Tata Steel, causes a delay in the project, causing new negotiations to be necessary (Interview 4 & 11). **The allocation of potential risk,** making this project even more difficult, since all potential hazards had to be recorded, and allocated (Interview 11).

To conclude, the allocation of costs & benefits is mainly connected to the investment costs, and risks of the project. A disagreement on the allocation of costs & benefits could arise in the negotiations towards a contract in the network, in NRL 5. If this causes problems, the process towards an agreement is long -term, and potentially tedious, leading to a barrier in the collaboration (Appendix E.3: Uncertainty about the outcome).

Technological

Implement ability of Technology

Theory

In the theory on technology and its implementation, the theory of the Technology Readiness Level (TRL) is present[24] The theory presents a tool; the TRL, to indicate the level of development a new technology (Mankins, 1995, 2009). In the TRL, the implement ability of a technology in its technological environment; the system, or bigger machine in which the new technology is implemented, needs to be researched. This has to happen in TRL6 of the TRL system. In order to reach this level, the technology needs to have been tested in its technological surroundings. This testing of the technology is a technological scope on implementing a new technology. The implementation barrier, however, could also emerge because of the company that does not want to implement a technology, since it does not want to change (D 'agostino & Delaney, 2015)**,** or when policy is not stimulating the adoption of new technologies(Kemp, 1994). The final two examples show a different perspective of implementing a technology in its environment. The implement ability of a technology is further discussed based on the interviews.

Interviews

The implement ability of the technology was only mentioned by 2 out of 14 respondents in the sorting exercise, but from the interviews it became know that the implement ability was a potential barrier. From the interviews the notion came forward that the technological barriers were absent, because the respondents indicated that technology wise, all problems could be solved in the projects concerned. Interview 8, however, mentioned the fact that the project cannot be seen separately from its environment. Whether the environment is the company processes, the corporate culture of a company, or the introduction of the technology in the surroundings, there is always a connection with the environment. If the project cannot be implemented in the surroundings, a barrier for the collaboration emerges. Different **feasibility studies** are needed to find out whether the technology can be implemented in surroundings, and processes. According to interview 2, in project, the process goes from feasibility studies to basic engineering, and finally a 10% accurate calculation of the technological aspects of the project. Besides feasibility, other factors influence the implementation of a technology negatively.

The implementation of the new technology in a company has to do with **the corporate culture,** and the possibility of introducing new projects. During the wind turbine project, many individual actors were opposed to the project, because it impacted their responsibility area of the terrain of TSIJ (Interview 3 & 8), which caused a delay, and tedious process before the actors agreed on the wind park to be build. In this case, **the internal corporate culture hindered the collaboration**, according to interview 4.

In the solar panel project, on the one hand, the willingness of different facility managers to install solar panels on the roofs of their production units, was present (Interview 4 & 15), which lead to fast assessment of potential roofs for the projects. However, **the technological implementation** of the solar panels was a problem in this case, due to the age of the roofs, and the need for replacement of roofs to be able to hold the solar panels (Interview 4 & 15).

[24] The TRL is explained in paragraph 5.1 of this thesis.

Finally, the spatial **environment of the technology** needs to be known, since this could potentially cause a barrier, both in terms of technological characteristics, and actor interests. A wind park which is developed has impact on its surroundings both. Besides the technological implement ability, the inclusion of local residents, local government, and interests groups is a must in these projects, according to four interviewees. Besides this, the wind park, but also other projects in which a technology will be implemented, can never be seen on its own. The project is always interconnected with other current projects, future ideas, and already existing structures (Interview 8). As an example, in the development of Wind Park Ferrum a potential partner for the development was also partner in the development of another wind park, which was opposed by Tata Steel. This opposition existed because of concerns on safety issues (Interview 3). Engaging with this actor in the Wind Park Ferrum project would have been a problem due to the conflicting situation in the other project, showing the importance of the environment of the technology, both in terms of technology, and of actors, and other projects.

To conclude, the implement ability of the project is not only related to the technological implement ability. If a technology is non –implementable in the technological environment, this becomes clear in NRL 5, after the feasibility studies have taken place. If a company is not willing to adopt the new technology, or presents all sorts of arguments not to implement the technology, the internal corporate culture hinders the network, which is potentially the case in NRL 4. In NRL 5, the further research on the feasibility of the project, brings new insight into corporate culture, because the actual implementation is researched. One could say that the corporate culture already hinders the collaboration before this, if there is no willingness to share resources, but this is in a beginning stage of the network, not yet determined by multiple actors within the company, but just the people doing the first meetings, and the management.

Concluding Remarks Barriers

In the previous paragraph, the barriers of collaboration in a network are presented. The most important barriers of collaboration come forward from coding class of **collaboration**; the conflicting interests among actors within a network, and the uncertainty about the outcome of the collaboration... Besides this difficulties in sharing of knowledge, coming from the coding class of **communication** is a barrier of collaboration. The factors are again related to the soft factors of collaboration.

On the other hand, the absence of a business case, and disagreement on the allocation of costs & benefits are mentioned as barriers of the **economic** coding class. Besides this, the **political** factors of constraining rules & regulations, and the absence of rules& regulations cause uncertainty in the projects. A clear level playing field of collaboration that should be created by the politics is consequently absent. Due to uncertainty, absence of subsidy, or clear policy, business cases remain negative, leading to missed chances. This shows the connection between economy and policy, both as factors determining the level playing field of collaboration.

Finally, the non -implement ability of the **technology** could function as a barrier, since the technology needs to be implemented in its environment. The environment, whether related to the process, company, or surroundings, could cause barriers.

To conclude, the soft variables in terms of the conflicting interests, and the willingness to share information are again barriers of collaboration. The economy and political dimension of collaboration form the conditions of collaboration, by creating the level playing field of the collaboration, through constraining rules, uncertainty, and the absence of a business case.

Appendix F

Summary of the Literature Gap

Different theories are studied on how network development takes place, and are combined into a theoretical framework for network development in paragraph 3.2.3. This was done because of the exploratory character of the research into the NRL creation, and the absence of a framework in theory. A gap in literature existed because the theoretical framework did not exist, as a first reason, moreover the indication of the development of a network on a level scale was not present. The insights from different theories are presented in the table on the following page, to show the gap in literature. The table shows what was used from each theory, but also what was missing in a theory in the author's opinion. In the table on the next page, four theories are summarized, and the background NRL is presented next to these summaries. In this way the table shows how the different theories influenced the idea of the NRL draft.

Author	Newell – Network Management for R.E.	Hauber & Ruppert-Winkel – Three Phase Model	Hekkert – Functions of Innovation	De Bruijn – Process Management	Groenendaal – NRL - indicator
Phases	No Phases of Development	3 phases; (1) the pioneer phase, (2) the pivotal network phase, (3) extended network & emerging market phase	4 levels of development (Pre-development, development, take-off, acceleration)	Process Managerial vs. Project Managerial Phase consisting of different steps that have to be taken.	7 levels in the NRL (Heading + motivation for each heading)
Network Substance	Network develop-ment strategies of Process Design, or Institutional Design aimed at three characteristics: - Substance - Structure - Process	Streams of 'Network Elements' that are followed throughout the phases.	7 functions of systems (Functions that need to be supported by the system. Different functions will have influence during different phases of development)	Different actors, institutions, and content factors influencing the Process	16 criteria of a network of actors in a socio - technical system connected to different levels of development.
Indicators	No indicators	No indicator for the specific phases of development	Indicators (One sentence describing the functions + diagnostic questions)	4 core elements of Process Design, and 16 elements that determine success	Criteria coming forward from literature, and interview results
Missing in the publication	No phases of development, or factors influencing network development indicated	Following different streams of factors throughout the system, instead of steps connecting to a factor. No names connected to LoD.	Fails to connect the functions to clear level of development. No insight into when what factor is influencing	Fails to connect the influencing factors of the process to a level of development.	A clear indication of the level of development, without remarks on what is lagging behind.
Lessons Learned	Division of network framework over three characteristics of network development.	Importance of changing factors over time, and the idea of connecting them to different phases of development	The importance of different factors influencing the development process over time	Different internal, and external dynamics causing a change in management strategy over time	No lessons learned from the theory as of yet, only on the creation of the NRL -indicator.

Appendix G

Incentives to Engage in a Collaboration

One of the questions asked during the first part of the interviews was: '*What starts, or triggers collaboration between parties in the [name of the project] project?*'. The question was asked to obtain an insight into what incentivizes actors to engage in a network of collaboration. A distinction is made with respect to the type of incentive. During the interviews it became apparent that the government has a connecting, and demanding role in development, therefore a driver to collaborate can be government prompted. On the other hand, the incentive to collaboration can come from different internal motivations, incentivizing the idea of collaboration. Therefore, the incentives are divided in these two types of incentives.

G.1 Government Incentives

Request by the Government

A **request by the government** to work on renewable energy, or waste heat development, gives an incentive for actors to look for collaboration. Governmental requests are incentivizing the idea of working together on projects, since the requests are offering the possibility to contribute to the energy transition, and serve the common interest. The fact that the provincial government had selected the IJmond region as a location for potential wind turbines on land, gave the incentive to look for possibilities, as interview 5 replied. The Province of Noord-Holland requested for 785 MW of wind turbines on land within about 20 searching areas. This request gave an incentive to wind park developers to look for collaboration with Tata Steel, included the OD NZKG as the licensing authority, and drew the environmental cooperation Wijk aan Zee into the discussion (Interview 1, 5& 10). For a DH - network, the OD IJmond brought parties together to participate in the project, after a first initiative by Tata Steel, according to interviewee 14. A lobby of the OD IJmond, in this case, caused the actors to gather in a network for the development of the district heating network (Interviewee 6). The OD IJmond tries to take control, and bind commercial and non-commercial actors in a network to develop the DH - network. The organisation facilitates collaboration without looking to the content of cooperation, leaving this to the actors in the network, trying to be the facilitating actor (Interviewee 14). This shows the direct incentive given by the supra –local, and local government to work together on renewable energy, and waste heat cases.

Demand by the Government

Opposed to a request by the government, incentivizing collaboration between actors, the National Government sets **requirements** that have to be met. One of these requirements is the 1% / year energy reduction agreement that Tata Steel has with the government, which gives an incentive to conduct energy related projects in steel making, but also renewable energy, and heat projects (Interview 1).The demand by the government creates an obligation to work towards a certain goal, creating a motivation to work on energy related projects. A demand gets hands on the table to get things done, according to Interview 2. This shows the government has a demanding role, but leaves the actual approach to the actors involved in the agreements. The government creates a framework, in which the different actors work together in a network. How to achieve the goals is left to the actors (Interviewee 1 &2).

G.2 Internal Motivation

Financial Gain

Financial Gain is the most important incentive to engage in collaboration in the energy related projects. The goal of the collaboration is to attain this financial gain by working together. This statement was shared by all interviewees, whether they were public parties, or commercial companies. However, the understanding of financial gain differs among the actors, due to their different activities. Financial gain is represented by the **profits made on an investment,** which is the incentive for parties with core businesses in energy related projects (Interview 1, 2 & 11). However, the bigger picture, and the other benefits of investment are considered as financial gains too. The actors representing the common interest, did not necessarily look for financial gain, but for the bigger picture, sustainability in general, or **redistribution of costs/benefits.** These factors were indicated as the gains of collaboration (Interview7 & 14).

Tata Steel did not look for direct financial gain by engaging in the energy related projects. This had two main reasons. Not only, the low electricity prices, and thereby long payback time, but also the lack of investment budget (Interview 2). The company prioritizes core business investments, and looks for investors for the energy related projects (Interview 1, 2 & 11). The profit is not expressed in direct financial gains, but should be created over the whole **value chain** of the projects through for instance; saving on electricity costs, reducing materials, and process improvements (Interview 2). Besides adding to the value chain, the value of the **image** of energy related projects is important. PR -value is an important driver of conducting energy related projects (Interviewee 4). Installing solar panels, and engaging in the development of a wind park provides a green image (Interview 15). The fact, however, that these projects do not make direct financial gains reduces the attention for the projects, and makes actors move on to the order of the day. Therefore a change of mind, and more emphasize on the **contribution to the bigger picture** could help in incentivizing these type of projects (Interviewee 6). The focus of the company in collaboration should be more on connecting, and taking the responsibilities in terms of contribution to the energy transition, than on pursuing financial gains.

PR driven

As was mentioned in the previous paragraph, the value of the **corporate image** is becoming more important, and was an incentive to cooperate in energy projects. Installing solar panels at the TSIJ –facilities, or building wind turbines on site will only cover a very small amount of the total energy demand. The value is in the image of TSIJ trying to add as much as possible to the energy transition (Interviewee 4 & 11). Besides this, the value is in being a **responsible neighbour** by including local residents in the decision processes, or participation in the projects (Interviewee 3). Also from the other side; constructing the largest roof tied solar panel project in the Netherlands, or building a new wind park on the TSIJ –site gives PR –value to actors in the network.

Necessity to work together

The necessity to work together becomes an incentive because of two reasons. At first, since the **expertise** is missing in an individual actor to conduct energy related projects alone. Tata Steel produces steel, and does not have experience with solar panels, wind turbines, or district heating networks (Interviewee 3 & 11). Therefore, other actors need to be involved to conduct feasibility studies, to facilitate the cooperation, and to apply for permits. For example, the OD IJmond facilitates the collaboration for the DH –network, and approaches other actors with expertise in DH –networks (Interviewee 14).

Besides the expertise that is missing, the **role of the actor,** demands cooperation. Tata Steel provides the space for solar and wind energy, but will not do the investment, and will not conduct feasibility studies (Interview 1, 2, 3 & 11). In the district heating case, the company provides the heat, but will not invest in infrastructure, or create the demand (Interview 1). To add to this, the operator of a DH – network does not have the possibility of providing the heat by itself, and a company that could provide the heat in combination with the network, does not have the possibility to create demand (Interview 6&9). This shows that actors are dependent on a collaboration to execute these projects, causing a necessity to work together.

Sustainability Driven

In the philosophy of Tata Steel, the company exists not only by grace of society, but also to contribute to society. The company adds to society by producing steel, but the focus is more and more on contributing to the energy transition, which causes an urgency to collaborate (Interviewee 5 & 8). For instance by listening to external parties offering innovative technology for heat storage, and engaging in collaboration (Interview 1 &2). Also by supporting the idea of Raedthuys to request for SDE+ subsidy for the solar panels (Interview 4 & 11), or working together with Infinergy & Stichting Milieufederatie Wijk aan Zee for participation options in Wind Park Ferrrum (Interview 3,7 &8). This shows an intrinsic motivation to contribute to the energy transition, and to society. The projects are part of a bigger picture namely contribution to the Energy Transition. According to Tata Steel interviewees the questions that have be asked are: 'How to play our role in this bigger picture, and how to cooperate with other actors to achieve improvement for society?'. Our role is to connect people and collaborate to take our responsibility in the energy transition (Interview 5 & 8).

Final Remarks

Actors are motivated to engage in collaboration because of an incentive. This incentive is mostly financial, because of the financial gains. However, the trigger could also be given by a government demand, potential for PR value creation, or the pure necessity to work together. What actually triggers the collaboration is a combination of the incentives, and could vary over the different actors. Where commercial actors look for financial gain, or PR value, the public actors will represent the interest of the common, and look for value in protecting this.

Appendix H

Explanation of the SDE+ subsidy

The SDE+ subsidy, or Stimulering Duurame Energie, is the subsidy the Dutch government makes available for the stimulation of renewable energy development. The subsidy is valid for projects concerning; biomass, geothermal, water, wind, and solar energy, which means industrial rest heat is not included. Anyone connected to a company, or non –profit organization could apply for the subsidy in two annual opening rounds. One in the spring and one in the fall. The total available budget for the fall –round of 2017 was 6 billion euros (Rijksdienst voor Ondernemend Nederland, 2017).

The SDE+ subsidy is an exploitation subsidy, and distributes a subsidy to the producers of renewable energy. In the following explanation renewable electricity will be used, to prevent confusion. The SDE+ subsidy is needed, since the generation of renewable electricity is at higher costs than the generation of conventional energy, resulting in sometimes unprofitable generation of renewable electricity. This is based on the fluctuating market prices. The SDE+ subsidy aims to pay the difference between the market price for the electricity, and the cost price of the generation; the unprofitable summit (Rijksdienst voor Ondernemend Nederland, 2017). The SDE+ subsidy will only reimburse the difference between the cost price of generating renewable electricity, and the market price of the electricity. Figure F.1 could be used to explain the SDE+ subsidy. The red line, and the green bars are the market price of the electricity (Correctiebedrag / Marktvergoeding). The upper dark blue line is the generation costs of the renewable electricity (Basisbedrag). If the red line is below the upper blue line, the SDE+ subsidy (purple bars), will reimburse the difference between the market price and the generation price. The lower blue line is the basic energy price, and presents the lowest electricity market price for which the subsidy will reimburse. In the example of figure F.1, the SDE+ subsidy will not reimburse below an electricity price of 0,04 euro/kWh, which means a lower profit for the renewable electricity generating actor (RVO, 2017).

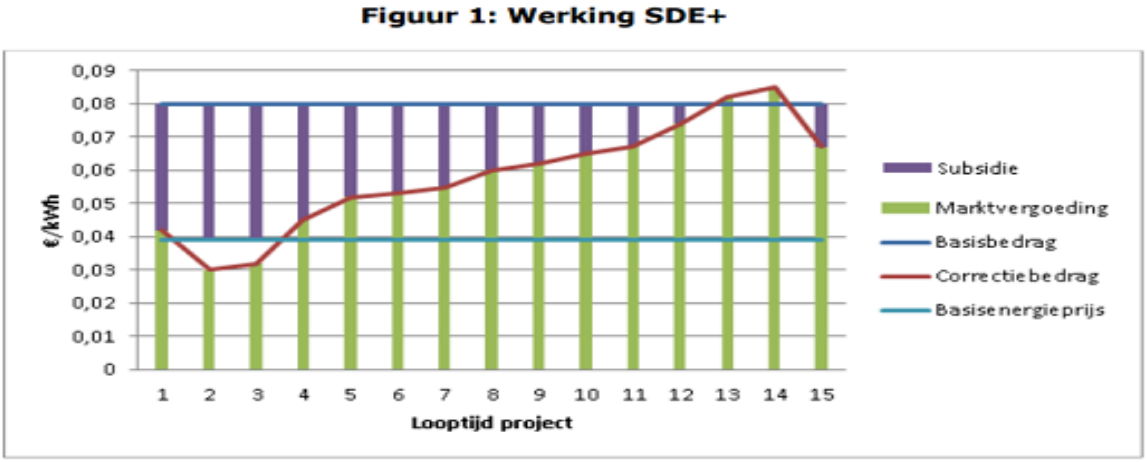

Figure H.1 – Graphical representation of the SDE+ subsidy for renewable electricity generation. http://www.energiebusiness.nl/2015/12/10/sde-2016-8-miljard-in-twee-rondjes/?doing_wp_cron=1531915880.1195878982543945312500

The SDE+ subsidy is determined for a period of 8, 12 or 15 years, depending on the type of technology. The subsidy starts at a specific date, if the technology is not installed at that specific date, this results in a shorter period of making profit. This happened in the Solar Energy at TSIJ case, since the start date of the subsidy was April 2018. At the end of each year the total subsidy amount is paid based on the generated amount of electricity, and the electricity market price.

The Basisbedrag (Dark Blue line) for electricity generation is again determined before each opening round, and is based on the average generation costs of renewable electricity. The same holds for the Basisenenergieprijs (Light Blue line). During the period of 15 years, it could happen that the electricity market price is below the Basisenergieprijs, which means a lower potential business case, due to a lower ROI. This is what happened in the solar energy case at TSIJ. The SDE+ subsidy was not sufficient to, since the market price dropped below the basisbedrag.

Appendix I

A fourth indicator method: the NRL / TRL matrix

In Chapter 7 on the results of this research, the NRL has been proposed as a method to indicate the level of development of a network. The Properties, Facilitators & Barriers (Table 1), the Sufficient Conditions & Indicators method (Table 2), and the NRL -indicator (Table 3) were described as methodologies to indicate a level of development. The input for the draft of the methodologies was obtained by interviews, in which sorting exercises were presented. The sorting exercises for the Facilitators & Barriers were structured by using different coding classes. The coding classes of: Collaboration, Communication, Political, Economic and Technological, were used. All presenting Facilitators & Barriers that could be chosen by the respondents. The coding classes not only structured the sorting exercises, but also provided the opportunity to indicate from which coding class the chosen facilitators and barriers were originating.

Based on the outcomes of the sorting exercises the notion emerged that the soft variables coming from Collaboration & Communication were influencing the collaboration in a network of actors the most. The coding classes provided facilitators and barriers that could not be neglected in a collaboration. The factors coming from the Political, and Economic coding classes had a more enabling function, by creating the conditions for the collaboration. The factors coming from the Technological coding class were not expected to influence the network development, since the technology was expected to be present, only to be implemented.

In the final NRL –indicator the outcomes of the coding classes were mixed, since individual criteria were presented to help indicate the level of development of a network. Therefore, the coding classes were not present in the final methodology. There is, to the author's knowledge, no methodology present that uses the different coding classes to indicate a level of development. A tool that, when a specific network is researched, provides an insight into the current state of the network. Besides this, indicates what factors, from which coding class influence the development of the network further.

In this paragraph, therefore a proposal for a different methodology to indicate the level of development is proposed in the form of a matrix that combines the coding classes of this research. In the matrix, a network can be filled in, and the factors influencing the further development of the network can be indicated.

I.1 the NRL / TRL Matrix

To present a network in the middle of factors originating from different coding classes, a matrix is used. The idea of the matrix is obtained from the NRL/TRL matrix that Krijger proposed in his works on the NRL. In his works, the x-axis of the matrix presents the TRL, presenting the technological assessment of the network. On the y-axis, the NRL is placed, able to assess the network development. The same structure is used in this research, since the idea is to cover all the coding classes within one graph. By using the NRL/TRL matrix, the coding classes of Technology (TRL), and Collaboration, and Communication (NRL), are present in the network. The Political, and Economic coding classes are, however, not mentioned yet in the NRL/TRL matrix.

The Economic, and Political coding classes create the level playing field of a collaboration, by enabling a collaboration (par. 6.1.2 & 6.1.3 & Appendix E). For example, a positive business case enables the further development of a project, because a financial gain, just as rules & regulations enable the further development by creating boundaries, and clarity. The Economic, and Political factors are therefore represented as a boundary, or peel around the NRL/TRL matrix, literally representing the level playing field of the collaboration. The factors influence the further development of the network in the NRL/TRL matrix.

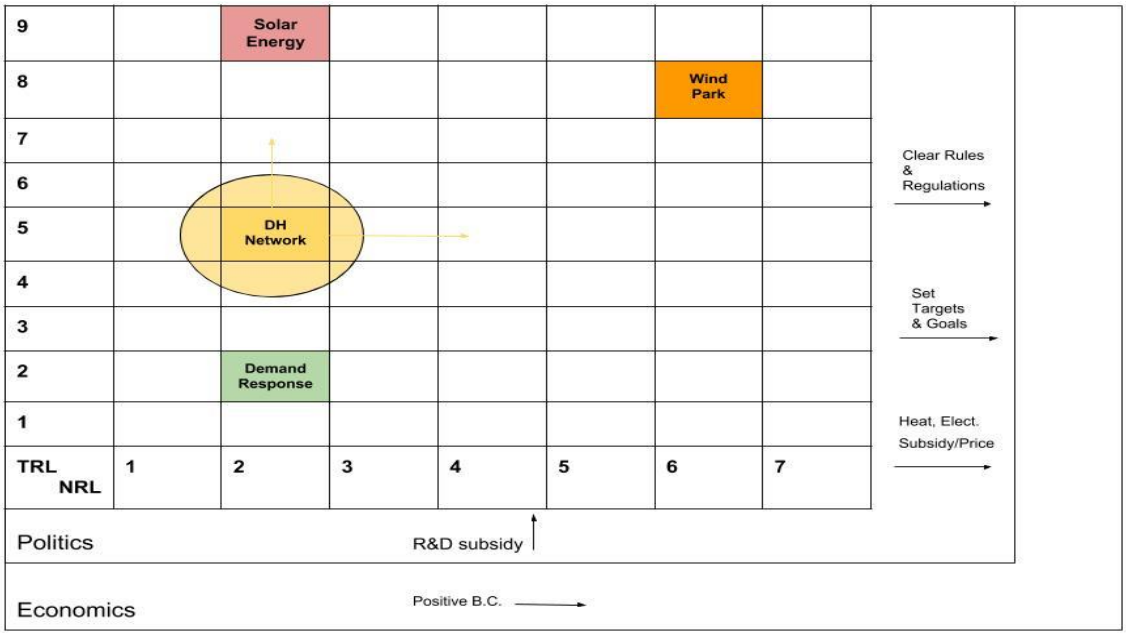

Figure I.1.1 – The NRL/TRL matrix with the Political & Economic factors as a surrounding peel, influencing the further development of the network. The cases of Tata Steel are included in the matrix based on their NRL & TRL value.

In the matrix, a network that is influenced by the economic, political, technological and the collaboration factors could be inserted. The network should develop towards the top right corner of the matrix. In this corner, the TRL and NRL of the network are high, meaning technological potential, and a developed network. The NRL -scale determines the soft factors of influence on the collaboration, the TRL -scale the technological factors. The Political and Economic factors are case specific and should be filled in for each network individually.

Some examples of the political and economic factors are given in the peel around the matrix in Figure B.1.1. A positive business case makes the state of the network develop to a higher level. Clear Rules & Regulations, set Targets & Goals, and Support by Decision makers, create the level playing field of the network, and positively influence the development of the network. The political factors do not always have to work supportive, but could also function as negative incentive. For instance restrictions on the spacing of the wind park, or a reduced amount of subsidy, would negatively influence the network development. The factors could be filled in by the user of the matrix based on the case he is researching.

If the factors of the different coding classes are indicated and added to the matrix, the matrix should provide an overview of factors from a technological, economic, political, and network perspective, thereby providing a different methodology then the NRL –indicator. The methodology has both positive and negative sides in determining the level of development of a network

Positive Aspects of NRL/TRL matrix

- A clearer insight is obtained into where (which coding class) the factors of influence on a network are originating from. It is easier to indicate where effort needs to be put to further develop the network, or indicate what is holding back the development.
- A more network specific tool is created, because for each individual network the political, and economic factors have to be determined.
- By placing the network in the matrix, the network is placed in a force field of factors, showing what influences the network from different perspectives.

Negative Aspects of NRL/TRL matrix

- For each individual network, the political and economic factors need to be indicated, which is a time consuming task, and sometimes not possible even.
- The methodology does not provide a clear level of development of the network, but places it in a matrix in which the factors of influence are shown. The outcome of the indication, thus is a matrix of factors. The applicability such a matrix has not been researched before, and needs validation.

I.2 The use of the NRL/TRL matrix

The NRL/TRL matrix could be used to see how the different perspectives influence the further development of the network, either hindering or facilitating. The case of a network could be inserted into the NRL/TRL matrix, and the peel surrounding it could be filled in with the case specific factors. The TRL and the NRL can be determined with the methods presented in this research. The Political, and Economical dimension create the level playing field of the network.

In the DH –network case, the TRL is high; TRL 9, since there has been proven application of the technology. There are, however, doubts on the technological development of open networks, with heat sources of different temperature, and cascading of the heat. This places the TRL of the network lower; TRL 7. The NRL of the case is in NRL 2, since the network has been brought together again, with a new actor involved. First talks are taking place, but no LOI is signed yet, and no clear tasks have been determined. The political dimension influences the case by the fact that there is political uncertainty. There are no rules & regulations on the development of DH –network, which causes uncertainty, and stalled investments. Besides this, there is no subsidy available, and no clear policy on the future of the heat market model. These factors have to be included in the political peel of the matrix. The economical dimension shows negative business cases for the DH- networks, due to legal uncertainty, no connection between supply and demand, and the small scale of development. These factors have to be included in the economic peel of the matrix. By combining the different dimension in the framework, the case is placed in a field that shows all factors of influence. The user of the matrix receives this overview, and could reason what impacts the most, and what should be done to develop further. The matrix thereby is an indication tool, explicitly mentioning the political, and economic dimension of the network development.

The matrix could be used by policy makers, and managers to obtain a clear overview of the network. Based on this overview, decisions into further actions could be taken. Both in the direction of further technological development, if the TRL is not at the highest level, or at the social aspects of the collaboration, if the NRL is not at the highest level. Influenced by the conditions of the economic, and political factors, surrounding the network.

ENERGY RESEARCH & SOCIAL SCIENCE 00 (2014) 000–000

Available online at www.sciencedirect.com

Energy Research & Social Science

Journal homepage: www.elsevier.com/locate/erss

The Readiness Assessment of the social dimension of a socio -technical system: the NRL –indicator

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Elsevier use only:

ARTICLE INFO

Article history:

Keywords:
Network of actors
Collaboration
RE development
Assessment
Readiness of a network
Level Scale

ABSTRACT

Collaboration in a socio -technical system takes place in networks of actors. In these networks, actors supporting different interests, capabilities, and backgrounds work together to create technological output. A readiness scale for the technical dimension of the system exists, in the form of the TRL, but a scale to assess the readiness of the network of actors is absent. This paper presents a scale and methodology; the Network Readiness Level –indicator (NRL –indicator) to determine the readiness of a network of actors on a level scale. Semi –structured interviews in combination with a sorting exercise were conducted with experts to validate the properties, facilitators, and barriers of influence on a socio -technical system. The results were used in 4 -step result analysis leading to different versions of a NRL –scale. As a final outcome, the NRL –indicator was drafted based on 16 criteria of collaboration and is able to assess the readiness of a network of actors on a numerical scale. The indicator could be applied in different networks of actors. The NRL –indicator described in this paper only represents a first draft of a new methodology, therefore, validation, and adaptation are suggested.

1. Introduction

1.1 Background and Motivation

In recent years the need to collaborate in a network of actors to contribute to the energy transition has been expressed (ECN, 2015; ECN, 2017) (Mattes, 2016; McCauley & Stephens, 2012; Schonberger, 2013). As a consequence the lower level of the actor network working on a socio –technical system in the form of renewable energy projects has become more important (Newell, 2017). In these networks of actors, different actors; individuals, groups, public and private organizations are collaborating to develop renewable energy projects (Agranoff & Maguire, 2001).

The system can be seen as socio –technical systems* in which technology is embedded in a social network of actors (Yang-Turner, Lau, & Dimitrova, 2011). By combining different actors in the network, different interests, opinions, and capabilities are present to develop the technical part of the socio –technical development. It ismainly these social, or 'soft' factors of collaboration that could further influence the collaboration (Corsaro, Cantù, & Tunisini, 2012; Lippert & Nyerki, 2011;Flyvbjerg, 2003).

Combining different actors in a network, with each actors supporting a different interest, possessing different resources, and perspectives, becomes a difficult task (Newell, 2017; Negro, 2012; Lutz, 2017). For assessing the technical dimension of the socio- technical system, the Technology Readiness Level (TRL) exists. A scale of nine

levels of development (TRL 1 – TRL 9) that is able to assess the readiness of a technological development. Structuring the development process, and unifying communication about the development(Mankins, 1995). For the social side of the socio –technical development, however, no such scale to assess the readiness of the development exists, besides a first proposal on to the Network Readiness Level (NRL), whereas it is these social factors of influence that are causing problems. The aim of this paper is therefore to find out how a numerical indicator could be drafted to assess the readiness of the social side of the development.

The NRL (Network Readiness Level) is an already existing numerical scale that could be used to indicate the readiness of the social side of the socio –technical development. The network in this case is a network of actors working together to stimulate the socio –technical development. A first proposal of the scale was made by Krijger, the author, however, states that the scale needs further research, and a practically applicable scale needs to be created. His works focus on presenting the idea, but do not specify how to draft the scale, and how to create a practically applicable scale. This opened up the possibility of a more elaborate research into the NRL- scale to answer the following research question: *'How to develop a numerical indicator to assess the readiness of a socio-technical development?'* In this paper the results of a research into the draft of the numerical indicator are presented.

This paper is structured in the following way. The research methodology used in this research is presented next (Section 2). (Section 3) presents a study of the NRL of Krijger, and tries to indicate how an improved version could be drafted that is better applicable to practical cases. Based on the research method of Krijger, and a new theoretical framework. The cases on socio –technical system development that were used for data generation in this paper are briefly introduced in (Section 4). The main section of this paper (Section 5) presents the results of the paper in the form of three tables of results, representing different version of a NRL –scale. The results are discussed in (Section 6). Finally, the paper is closed with a conclusion, and recommendations on future research (Section 7).

2 Methodology

2.1 Research Design

In this paper, a desk research into the existing NRL –scale of Krijger, and his methodologies was done. Krijger used a case of introducing demand response in a network of actors as a source of data on socio –technical development. He presented the idea of using a sorting exercise of properties, facilitators, and barriers of influence on a socio - technical system to extract data and expert opinions from the case. The sorting exercise was included in semi –structures interviews, that were conducted to find out what the factors of influence were. The method of using a sorting exercise in combination with semi –structure interviews was used in this research too. Besides this, the works of Krijger showed the use of a rather thin theoretical framework, that needed improvement

2.2 Literature Studies

Two preliminary literature studies were conducted in this paper. The first into the draft of a new theoretical framework, using the following keywords: *'socio –technical development/transition', 'network development/management', 'renewable energy project management', 'renewable energy development', 'theoretical framework network management'.* The second into the factors of influence on a socio –technical development. The following keywords were used in this literature study: *'influencing factors socio –technical development', 'barriers socio –technical development/transition', 'facilitators socio –technical development/transition', 'properties socio –technical development/transition', 'barriers/facilitators of collaboration (in projects), 'collaboration in networks of actors', 'soft –factors in collaboration'.*

2.3 Data Collection

The literature study into the factors of influence on a network of actors lead to list of properties, a list of facilitators, and a list of barriers. The meaning of the PFBs was:

- Properties; factors that have to be present in the socio –technical development, factors that are specifically connected to collaboration.
- Facilitators; factors that help the socio –technical system develop further.
- Barriers; factors that hinder the further socio – technical development.

These lists of factors had to be validated in order to function as an input of the NRL –scale draft. Therefore, semi –structured expert interviews, in combination with a sorting exercise were used. Semi –structured interviews are the most appropriate way of capturing the dynamic character of collaboration processes (Mattes et al., 2015). The semi – structured interviews were combined with a sorting exercise, that was formed with the three lists of factors of influence.

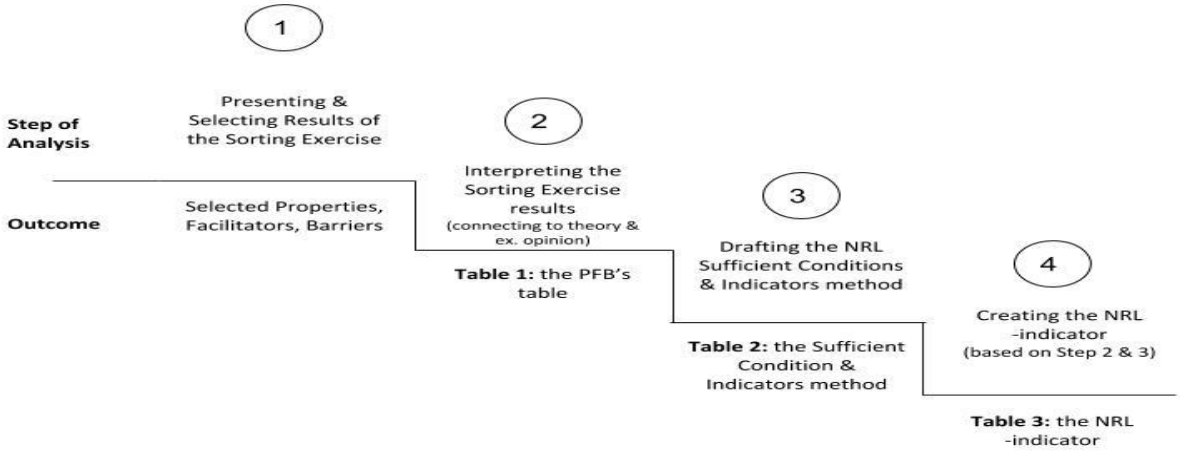

Figure 1 – The 4 –step result analysis method. Each step of analysis represents an action that leads to the an outcome. The final outcome in step 4 is the final result of this paper.

2.3.1 The Sorting Exercise

The sorting exercise in this paper was derived from the Q –sort methodology in which respondents are asked to rank all factors that are present in the ranking exercise from high to low, based on their importance (Exel & Graaf, 2005;McKeown & Thomas, 1988).

The sorting exercise in this research was changed slightly from the Q-sort exercise, since not all the factors of influence had to be ranked, but only a top five. The sorting exercise asked the respondents to rank the five (1 = most important; 5 = least important) most important properties.

In the sorting exercise of the Facilitators & Barriers, the coding classes had to be ranked (1 = most important; 5 = least important), and the individual faciliators and barriers had to be mentioned. The coding classes are introduced in section 3. The sorting exercises generated numerical data on the number of times chosen value of a property, facilitator, or barrier of collaboration (Number of Times Chosen out of Possible Times Chosen), and an average sorting value (Number of Points Received / Number of Respondents).

Besides filling in the sorting exercise the respondents were asked for a motivation of why the specific factor was chosen, so a discussion on the factors of influence on a collaboration could emerge. In this way numerical data was gather, and an expert opinion on the factor of influence.

2.4 The Cases of Tata Steel IJmuiden

To validate the lists of factors, and conduct the sorting exercise, experts were needed. The experts needed experience with working in projects on a socio –technical development.. Therefore, different cases on the development of renewable energy and a DH –infrastructure of Tata Steel IJmuiden were studied as an example of cases of socio –technical development. Research on the cases lead to the selection of three cases of socio –technical development.

All the cases were conducted in a collaboration with multiple private, and public actors willing to stimulate a socio- technical development. Based on internal documents are preliminary lists of experts was drafted that were active in the cases. This list was further extended through snowballing. A total of 15 experts was found to conduct the semi –structured interviews and the sorting exercises with.

The numerical data in the form of the ranked factors were used to indicate the most chosen factors of influence in the research, however, due to the sample of 15 respondents, the absolute (quantitative) values are not that relevant. More emphasize is put on the outcomes of the sorting exercises, in combination with the motivation of the experts, and their opinions. These opinions were coded, and used to determine factors of influence besides the numerical values. In order to change the numerical outcomes of the sorting exercise, and the expert opinions into a new NRL –scale, four steps of analysis were used.

2.5. *Data Analysis*

A 4 –step method of result analysis was used to be able to draft the final outcome of this paper. The four steps and their outcomes are presented in Figure 1, and explained briefly:

Step 1- In the first step of the analysis, the properties, facilitators, and barriers are presented. Subsequently the factors are chosen, based on the number of times they are chosen by the respondents. The outcome is a table presenting the Properties, Facilitators & Barriers (PFB) that are the first input of the analysis. In the first step only the numerical outcomes of the sorting exercises are taken into account.

Step 2 – In the second step the selected factors of Step 1 were interpreted based on findings in theory on the specific factor, and motivations of the experts. The connection to theory was made to explain the factors further, and the motivation by experts to include the factors in Table 1. Extra PFB's were added based on specific expert opinions. The selection of these PFBs is based on the number of times they are mentioned, and the importance that was given to the factors by the experts. This resulted is an overview of all Properties, Facilitators & Barriers of influence on the social dimension socio –technical system based on the interviews. These are presented in Table 1 in which the PFB were connected to a level of development on the NRL –scale.

Step 3 – In the third step the PFB's of Table 1 were translated into Sufficient Condition & Indicators for each level of development on the NRL scale. The translation is based on changing the PFB's to an Indicator, and the draft of a Sufficient Condition for each level of development. The result is Table 2 presenting the Sufficient Conditions & Indicators method.

Step 4- The final step was used to include three characteristics of a socio –technical system in a new methodology for assessing the readiness. The final step of analysis is based on determining 16 criteria present in a socio –technical development. These criteria were selected based on the outcomes of the previous steps of analysis ,and formed the final outcome of this paper. In following section the NRL –scale of Krijger, and the literature studies are introduced.

3. NRL – scale of Krijger & Literature Study

The NRL – scale was proposed to determine the readiness of a network of actors to stimulate a socio – technical development, expressed on a level of development scale. The NRL –scale came forward from the idea that in a socio –technical development, both the technical, and social side exist. The technical part is represented by the technology that is developed, or implemented. The social part is represented by the collaboration between the actors in the system. For the technological part the TRL (Technology Readiness Scale) exists. The TRL was used by Krijger as an example for the draft of the NRL –tool, since the nine levels of development were an example of the seven levels of development in the NRL. Besides this, the TRL used specific descriptions for each level of development, which was adopted by Krijger.

The NRL –scale, however, was used to indicate an intangible object, in the form of a network, instead of a tangible object in the form of a new technology. Therefore, the author determined a valuable methodology capable of indicating the level of development. The methodology was based on a sorting exercise of predetermined properties, facilitators, and barriers of influence on a socio –technical development.

The outcomes of the exercise that had to be conducted by experts lead to the draft of two NRL –scales:

- **The Facilitators & Barriers Scale** that assigned the specific Facilitators & Barriers of influence on a network to a level of development.
- **The Sufficient Condition & Indicators Scale** that could be used to determine the level of development based on the fact that a Sufficient Condition was met, and different Indicators that were helpful to indicate whether the sufficient condition was met.

The two scales, but especially the Sufficient Conditions & Indicators –scale, were proposed to assign a NRL -value to a network. Less emphasis, however, was put on how to actually measure the NRL in practical cases. How to make the scale applicable to a collaboration in a network of actors? Besides the difficulty in applying the scale in practical cases, the researcher used a thin theoretical framework of (Dhanaraj & Parke, 2006) on innovation in network as a background for the research.

The study of the NRL –scale of Krijger thereby lead to the insights that the research methodology of the sorting exercise based on predetermined properties, facilitators, and barriers is valuable in the draft of the NRL –scale. A new theoretical framework, however, had to be drafted to structure the research. Therefore, a more elaborate literature study was conducted into creating a theoretical framework, and to draft of a list of properties, facilitators, and barriers as an input for the sorting exercise.

3.1 Drafting a Theoretical Framework

In order to structure the first outline of the theoretical framework, a framework of (Newell, 2017). was used.

Based on his works, a network of actors can be divided into three characteristics: Network Process, Network Structure, and Network Substance, according to (Newell, 2017). The Process is related to the interactions leading to development.

The Structure is related to the actors and their connections leading to a development.

Finally, the Substance is all that the network is about, in terms of the things that it is trying to achieve. This structure is adopted in this paper, the different characteristics, however, had to be researched further to be able to explain what they entail. Several publications proposed the idea of a central Network Process, that was influenced by the Network Structure, and Network Substance over time.. The Functions of Innovation theory proposes seven Functions of Innovation that have to be present in four different phases of development (Hekkert, Marko ; Heimeriks, Gaston; Harmsen, 2011) (Hekkert et al., 2007). The 3PM (Phase Model) introduces three phases of development to work towards a regional energy transition through collaboration.

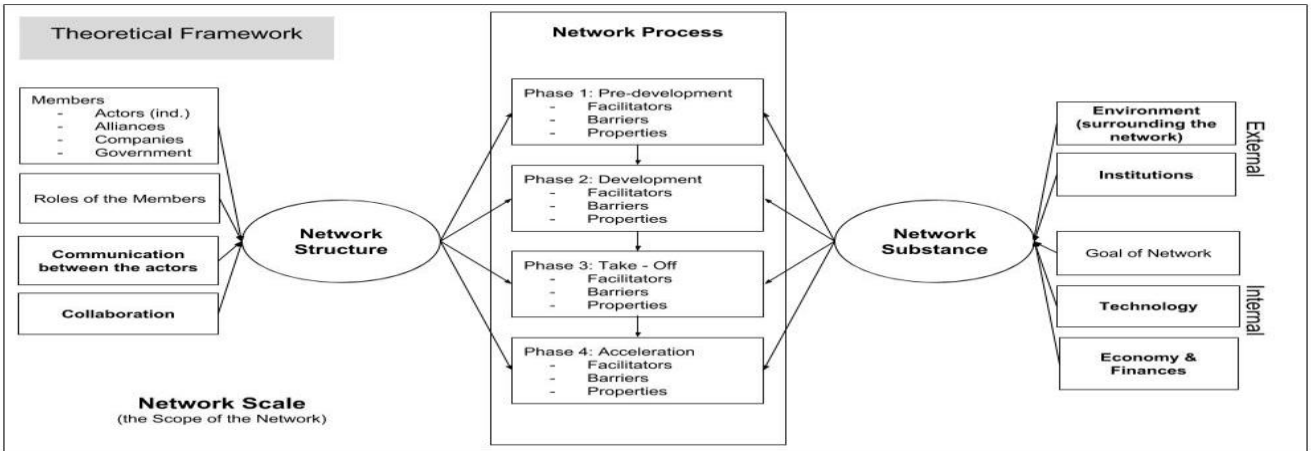

Figure 2
The theoretical framework that provided the coding classes in the sorting exercise of this research. The Network Process exists of different phases of development, which are influenced by different factors coming from the Network Structure and the Network Substance over time.

Each phase influenced by specific elements shaping the change of the network of actors in the collaboration (Hauber & Ruppert-Winkel, 2012; Ruppert-Winkel, Hussain, & Hauber, 2016). De Bruijn presents in his works on Process Management the existence of Internal & External Dynamics, influencing a process over time (de Bruijn, Hans; ten Heuvelhoff, Ernst; in 't Veld, 2006). This lead to the idea of the Network Process, that is developed over time influenced by different factors over time, that were originating from the Network Structure and Network Substance.

The factors coming forward from the Structure and Substance were divided over themes of factors. The themes of factors used were: Collaboration, Communication, Economy, Political, Technological, and Geographical. The division into the characteristics and the themes of influence on the socio –technical system lead to the draft of the theoretical framework presented in figure 1.

The Network Process is influenced over time by different factors coming from the Network Structure and Network Substance, summarized as the themes of influence. These themes of influence were input for the coding classes that structured the sorting exercises. Besides providing the coding classes for the sorting exercise, the theoretical framework did not have a function in the research, due to the new proposal and the need for validation.

3.2 *Creating the lists of Properties, Faciliators & Barriers*

Besides the theoretical framework that was drafted, a separate literature study lead to the draft of three theoretical lists of factors of influence on the socio-technical development. One list of properties, one list of facilitators, and one list of barriers These formed the input of the sorting exercises. The list of factors are presented in ***Appendix A*** of this paper.

4. The Cases of Tata Steel Ijmuiden.

The experts to validate the lists of factors in the sorting exercises were originating from three cases of socio –system development of Tata Steel Ijmuiden. The company wishes to contribute to the energy transition in all ways possible. This the reason why Tata Steel engages in renewable energy and DH –infrastructure projects that are not related to the core business of steelmaking.

It is these cases that have to be conducted with multiple internal/external and private/public actors. The cases selected were therefore suited to function as an example of a socio –technical system for the draft of a new NRL – indicator. The following three cases were selected:

(1) The development of Wind Park Ferrum

Tata Steel develops a wind park of multiple wind park at its TSIJ – site. In order to develop the wind park the company works together with different private, and public actors supporting different roles. The case thereby is an example of socio –technical development.

(2) Developing Solar Energy at the TSIJ –site.

The potential for roof –bound solar panels is large at the site of TSIJ, due to the more than 25.000m^2 of rooftops onsite. Tata Steel works together with other private actors to utilize the potential by installing solar panels on its rooftops. The case is thus an example of a socio –technical development.

(3) Creating a DH- infrastructure in the IJmond Region

The heat that Tata Steel generates in its production processes is a potential input for a DH –infrastructure, heating homes and offices in the IJmond. Region. Therefore, Tata Steel is engaged in a collaboration to develop a DH- network, connecting supply and demand of industrial heat, working together with multiple public and private actors. The final example of a socio –technical development.

From the three cases a total of 15 experts was selected to conduct the sorting exercises.

5. Results

In this section the results of the sorting exercise are analyzed in the 4-step method of data analysis explained in section 2. The results are presented based on this 4 –step method. Each step of analysis presented new results, and a Table that could be used for assessing the readiness of the socio- technical development. The outcomes of each step are presented, with as a final outcome a new methodology for NRL – indication.

5.1 Step 1- Selecting the Results of the Sorting Exercise

The selected PFB's based on the numerical outcomes of the sorting exercises are presented in Figure 3. The outcomes of the sorting exercise lead to the selection of seven properties of collaboration.

Ranging from the presence of trust (mentioned by 13 out of 14), and a shared vision (10 out of 14) to appointing a central coordinating actor (7 out of 14). A total of eight facilitators were selected, distributed over four different coding classes. The coding class of Collaboration received the highest average sorting value, which means that the facilitators coming from the collaboration coding class were considered the most important by the respondents. Four facilitators of the coding class of Collaboration were selected based on the numerical results; willingness to share resources/knowledge (12 out of 14), the central coordinating actor (7 out of 14), presence of key actors (7 out of 14), and well –established relationships at the beginning of the collaboration (6 out of 14).

Further the alignment of interests was considered an important facilitator of collaboration (11 out of 14), as was the support by political decision makers (10 out of 14).

A total of ten barriers were selected based on the outcomes of the sorting exercise in which again the coding class of Collaboration received the highest average sorting value. Of the barriers, the barrier of conflicting interests (10 out of 14), lack of trust (8 out of 14), and disagreement on the allocation of costs and benefits (8 out of 14) were mentioned most.

5.2 Step 2 – Interpreting the Sorting Exercise Results

The numerical results of the sorting exercise were connected to the theory on the PFB's and the remarks made by respondents. Based on these remarks **Table 1** was drafted (figure 4), connecting the PFB's to a level of development. Table 1 is indicates the factors of influence on a collaboration. Two important insight were obtained from the second step of result analysis. The properties; Trust, Shared Vision, and Transparency, cannot be missed in a collaboration that aims to stimulate a socio –technical development.

They are the starting point of any collaboration, and need to be present in the development. The properties are therefore considered as the pre –conditions of collaboration. Besides this, the factors of influence on the collaboration (all the PFB's) could be divided over Process Factors, and Product Factors. In which the Process Factors are the 'soft' intangible factors of influence, like trust, shared vision, and the bigger picture of the socio –technical development. The Product Factors are the physical products of collaboration; a LOI, a contract, a business case, or appointing Central Coordinating Actor.

The Process Factors will influence the collaboration in the beginning of the development, since they need to grow during the first stages.

Some facilitators that were mentioned are: the need to create a shared image of the collaboration, the need know the background of the other actors involved, and the change of mind-set from individualistic to cooperation in a network.

Properties	**Facilitators**		**Barriers**	
Formal contracts	**Collaboration**	Willingness to share resources/knowledge	**Collaboration**	Conflicting interests
LOI/DOI		Central Coordinating Actor		Lack of trust
Central coordinating actor		Presence of Key Actors		Uncertainty about the outcome
Shared Vision		Well established relationships		
Trust	**Communication**	Alignment of Interests	**Communication**	Knowledge sharing difficult
Reliability		Set Targets & Goals		Withholding of information
Transparency	**Political**	Support by Decision Makers	**Political**	Legal constraints
				Legal uncertainties
	Economic	Financial Gain	**Economic**	Disagreement on allocation of costs and benefits
				Disagreement on sharing of risks
			Technology	Non -Implement ability of the technology

Figure 3

The Product Factors are primarily an outcome of the growth of the process factors. They serve as formalization, or physical outcome of the development. As one respondent stated: 'The contracts are nothing more than a formalization of what was discussed between the actors to make sure everyone has the same image of the collaboration'.

In this way a distinction exists between the first levels of development in which the Process Factors influence the development, where the Product Factors formalize and create clarity in the later phases of development. The outcome of Step 2 of result analysis is presented in ***Appendix B.1***

5.3 Step 3 – Drafting the NRL Sufficient Conditions & Indicators Method

For each level of development, a Sufficient Condition in combination with Indicators (Process & Product) are translated from the PFB's of Table 1. This is done to create the Sufficient Condition & Indicators- method for assessing the readiness of the socio –technical development. Table 2 can be used to really determine the NRL of a network based on the Sufficient Condition. The sufficient condition drafted for each level of development were:

NRL 1: An incentive is present to engage in a project requiring collaboration

NRL 2: The specific requirements of the project are drawn up, partner selection/inclusion has started, and the pre conditions of collaboration are developing.

NRL 3: All potential actors are present in the network to stimulate the socio –technical system development and an LOI is drafted. Collaborative interest of the actors develops.

NRL 4: The LOI is signed and the risks, costs & benefits are indicated, and allocated among actors based on different feasibility studies. The bigger picture of the collaboration is present.

NRL 5: The feasibility of the project is clear in terms of finances, and technology, which leads to the draft of a concept contract.

NRL 6: The network has been set -up entirely, and has final formalization in terms of a signed contract.

NRL 7: The network has worked together, which results in the start of the project execution. .

If a sufficient condition is met, the level of development of the met condition can be assigned to the socio –technical development. If the Sufficient Condition of both NRL 3, and NRL 5 are met, NRL 5 is assigned, due to the highest met condition.

Each sufficient condition is supplemented with multiple process and product indicators that should help in indicating whether the sufficient condition is met. As can be seen from the different Sufficient Conditions, but also from the Indicators in Table 2, the development starts with the Process Factors, and works towards structure leading to the inclusion of the Product Factors of the network come forward. The Sufficient Condition & Indicators method is presented in Table 2 in ***Appendix B.2***.

5.4 Step 4 – Creating the NRL –indicator

In the previous step the Sufficient Condition & Indicators – method for the determination of the NRL was presented. This method, but also Table 1, do not include three important characteristics of collaboration to stimulate a socio –technical development. These characteristics came forward during the research:

1. The development is **dynamic,** due to progress, but also steps back, due to negatively influencing factors. Different events could happen that make the level of development return to a lower level. This is not included in the Sufficient Conditions & Indicators –scale, due to the strict Sufficient Conditions that have to be met. There is no swift method to show the dynamics of development.
2. **Indicators of different levels** of development will be **present at the same time**, making the determination of the level of development hard. Uncertainty might arise on whether the development is in NRL 3, or NRL 4. Should strict a Sufficient Conditions –scale be the outcome? Or should a more flexible method be used to assign a level of development? A method that is capable of showing the presence of indicators from multiple levels of development might be practically better applicable.
3. An indicator of a specific level **develops over time,** and is not absent on the one day, and present on the other. The Sufficient Condition & Indicators –scale does not allow for following an indicator throughout the scale, to allow for a more elaborate overview of a collaboration. For example trust is not present on one day, whereas it was absent the day before, but it builds over time, potentially spanning multiple levels of development.

These three characteristics are missing in Table 1 and Table 2, but should be included in new methodology in order for it to be practically applicable. Therefore a fourth step of result analysis was used to include the characteristics, and present a practically applicable methodology.

The outcome of the fourth step of analysis is the NRL –indicator. The NRL –indicator consists of 16 criteria of socio –technical development, based on the factors presented in **Table 1** and **Table 2.** As opposed to the method of Table 2, the NRL –indicator determines the level of development of a network of actors based on the presence of the criteria, instead of using a Sufficient Condition. The NRL –indicator is presented in **Table 3.** The NRL –indicator is presented in ***Appendix B.3.***

The 16 criteria allow for the determination of a level of development, in combination with a remark on where a development lags behind, and needs extra effort by the actors. The 16 criteria are presented on the y-axis, and the 7 NRL levels are presented on the x-axis of the NRL –indicator. By following the criteria down from the top left criterion ((1) Incentive), the NRL of a network can be determined. At every criterion the user of the NRL –indicator could reason whether the criterion is present (blue)/developing (light blue)/absent (white) in the network.

If a criterion is Absent / Developing the user of the NRL –indicator should reason on what has to be done to include the criterion in the network. By following all the 16 criteria down, an overview is created of the criteria present and absent in the collaboration.

Based on the following statement the level of development can then be determined:

*The level of development is based on the level of the **final criterion** (started from criterion 1) that is present in the network at the moment of assessment, and **remarks on what criterion is lagging behind, and where extra effort** is needed, to stimulate the development of the socio -technical system.*

An example is given to clarify the statement. In order to follow the example, Table 3 needs to be used. The example is as follows: *If in a network, the Management/Key Actors are involved, but not yet committed to the network. The Bigger Picture of the collaboration is present, and the LOI is drafted but not signed yet. The readiness of the network of actors can be indicated with **NRL 4** as the level of development, based on the fact that the Bigger Picture is present. This is the final criterion present in the development, when following all criteria down from the first criterion.*

There needs to be a remark, however, on the fact that the LOI is drafted, but not signed yet, and the management is involved, but not committed to the network yet. This has to be done, since these criteria are following the Bigger Picture in the NRL –indicator, and are not present in the network yet. These are the criteria that lag behind in the development. Consequently extra effort needs to be put in these criteria to stimulate the socio –technical development.

Therefore, the NRL –indicator determines the level of development at NRL 4, and advises to work on the signing of the LOI, and making the management/key actors in the network committed. In order to use the NRL –indicator, a comprehensive road is presented consisting of 6 steps to indicate the level of development in combination with the advice on where the development lags behind.

6 Discussion

The discussion of this paper is divided into two different sections. At first the research method is discussed, followed by a discussion on the NRL –indicator.

6.1 Discussion on the Research

In this research, interviews were conducted with actors involved in a wind park, a solar panel project, and a district heating network. This means that the three projects were all related to the generation, or usage of energy. The three projects, however, were very different from each other in terms of the actors involved in the network, and the background of the projects. This made creating a generalizable methodology hard, since the insights of three different socio –technical developments had to be included.

To discuss further on the generalizability of the methodology. A general application in different networks asks for the validation of the NRL –indicator. This validation should provide insights into whether the tool is applicable, or should be adapted. A method to validate the tool could by indicating the level of development of socio –technical developments with different backgrounds, such as: renewable energy, pharmaceutical industry, construction, innovation networks, or public-private partnerships. An application of the NRL –indicator in these different developments would provide a broad overview in types of networks. Besides this, it would give an insight into whether the NRL –indicator is applicable, validating the applicability. A second method to validate the methodology is by using an expert validation. In this validation method a predetermined group of independent experts is asked to provide their opinion on the applicability of the methodology, and where this fails. This expert validation needs to be set –up in order to validate the research outcome, and the proposed methodology.

Besides the fact that the results of the research need validation, the limited heterogeneity among the respondents has an impact on the outcomes of the research. The respondents for the interviews came forward from the cases of Tata Steel IJmuiden. The different interview contacts were determined based on the case descriptions, and in consultation with employees of the company. A total of 15 respondents were interviewed to provide the data for this paper. There is, however, no indicator of the minimum number of respondents needed, so this number was based on the availability of the respondents based on the cases.

Of the 15 respondents, 8 interviewees were internal Tata Steel actors (of 1 interviewee the results are not used), and 7 were external actors, leading to a total of 14 respondents. Of the external actors, 5 were involved in a governmental organization, or interest group, and only 2 were involved in other (semi -)commercial parties.

This makes the outcomes of the research Tata Steel and government motivated, due to little diversity in the pool of respondents. In a following research, the pool of experts should be divided equally over different background to provide a less biased scope on the importance of different factors.

A different point of discussion is on the methodology used in this paper. The amount of factors under the coding classes were not the same for the barriers, and the facilitators in the sorting exercises. 26 barriers were presented to the respondents to choose from, as opposed to 22 facilitators.

This should have been equal to provide structure in the research. The same holds for the different number of coding classes that were used for sorting exercise for the facilitators (6), and for the sorting exercise for the barriers (5). The coding class of Geography was not included in the barriers' sorting exercise. These numbers should have been the same to provide a better structure to the sorting exercise, and equal results in terms of the chosen coding classes. Respondents asked repetitively why there was a difference in the coding classes. The answer to this was, that in the literature, multiple sources presented the importance of geography on a network (Hauber & Ruppert-Winkel, 2012; Ruppert-Winkel et al., 2016; Späth & Rohracher, 2010). Based on this insight the coding class of geography was included, but could have been left out.

6.2 Discussion on the NRL –indicator

The 16 criteria of the NRL –indicator are determined based on the outcomes of the interview results (Table 1 & Table 2). The criteria give an overview of the factors influencing a collaboration. There is no certainty on whether the number of criteria is extensive enough, or whether criteria have to be removed. The number of 16 is determined based on the most important properties, facilitators, and barriers, but it could have been 18 or 20 instead. The practical application of the tool needs to provide clarity on the number of criteria that have to be included.

A potential benefit of the 16 criteria is, that the criteria could be added, or removed, depending on the type of network. This is opposite to the rigid, and pre –determined structure of Sufficient Conditions & Indicator. The removal, or addition of criteria allows for changes in the NRL –indicator and makes it applicable to different networks. Just as the TRL was adapted to other sectors then aerospace engineering, by creating spin- off tools adjusted to specific market criteria (Mankins, 2009). If a specific criterion is very important for a network, this criterion can be added in a future research, to make the NRL -indicator suitable. The same holds for the removal of a criterion.

For example, if safety is very important in a network, or the fact that specific company rules are implied, these criteria can be added to the NRL –indicator. The addition of these extra criteria, however, can only be done under the condition that the criteria are included based on the same 4 –step method as used in this paper. Using this method of including the criteria ensures that the criteria are added based on the right motivations, and backed by data. A much more practical idea of adding extra criteria, or removing criteria, gives the user of the NRL –indicator the option to add/remove criteria. The user could add a criterion based on the importance of the criterion in the network of interest. This idea allows for a more practical application, because the NRL –indicator can be adapted to study any network. Before the NRL –indicator is used, extra criteria can be added by a single user, or by the actors in the network, based on consensus on the importance of the added criterion. This allows for a very flexible NRL –indicator, making the methodology applicable in different networks.

Finally, the order of the 16 criteria, from top to bottom in the NRL –indicator, determines the level of development of a network. This is true in the sense that the level of development is determined based on the final criterion that is present. If a different criterion would have been earlier in the order of the NRL -indicator, the level of development might have been different. This has to do with the chronological order of the criteria, which could be arbitrary. For example, there is no clear proof that the Shared Vision is present before the LOI is signed, this is only based on interviewee remarks. A research into the position of the different criteria in the NRL –indicator is needed to find out if the order presents reality.

6.2.1 The Application of the NRL –indicator

The NRL –indicator could be used as a management methodology for actors to determine the level of development of a network. The dynamic character of a collaboration asks for a temporary, but repetitive indication of the level of development. The user of the NRL –indicator could use the tool on a monthly basis to obtain insights into the changes in the network, and where extra effort needs to be put in the collaboration. By using the NRL –indicator with multiple actors during meetings throughout the collaboration, a shared indication of the level of development of the network of actors is obtained. This facilitates the discussion in a collaboration, creates the same image of the development among the different actors and makes different actors express their needs in the collaboration.

7 Conclusion, and recommendations

7.1 Conclusion

This paper has looked into the draft of a new methodology to assess the readiness of a network of actors on a numerical scale. The following research question has been answered: *'What should a scale to assess the readiness of a network of actors in a socio -technical system look like?'* The readiness could be indicated based on the factors of influence on the socio –technical development.

The factors of influence were indicated by properties, facilitators, and barriers, and validate through a sorting exercise with experts on socio –technical development. Based on the outcomes of the sorting exercise, and the experts opinions. The three properties of; trust, transparency, and shared vision were seen as the pre –conditions of collaboration. Factors that have to be present in a network in order to collaborate. The factors of influence could further be divided into the Process Factors and Product Factors. The Process Factors are the 'soft' intangible factors of influence on a collaboration. The Product Factors are the 'physical' products of a collaboration, which are needed for structure, and formalization of the collaboration. The Process Factors are influencing the collaboration in the beginning, while the Product Factors are important to formalize the collaboration, and provide the structure that is needed later on in the collaboration.

The results of the sorting exercises further formed the input of a 4-step result analysis that lead to the draft of a new methodology, and an answer to the research question. In the first step of the analysis the PFB's were selected based on the outcomes of the sorting exercise, leading to a selection of seven properties, eights facilitators, and ten barriers of socio – technical development. These formed the input for the second step op result analysis. The combination of these factors with the theory, and expert opinions in the second step lead to the draft of Table 1, representing the PFB's connected to a level of development. This Table 1, however, could only be used to indicate a level of development, not assess it.

A third step of analysis lead to the draft of Table 2, consisting of Sufficient Conditions & Indicators of each level of development. This Table 2 was able to assess the level of development, based on the Sufficient Condition that was met, but proposed a very strict indication method.

Three characteristics of collaboration were missing in the method; the dynamic character of collaboration, the presence of multiple indicators at the same time, and the development of indicators over time. This lead to the draft of a new methodology; the NRL –indicator in the final step of the result analysis.

The NRL -indicator consists of 16 criteria of socio –technical development, divided over 7 levels of development (NRL1-NRL7). The NRL -indicator allows for assessing the readiness of the development by determining a level on a numerical scale, in combination with an indication on where the development lags behind. By repetitively using the NRL –indicator, the methodology allows for a temporary indication the readiness of the development. The NRL –indicator includes the three characteristics of collaboration that were absent in the Sufficient Condition & Indicators method by the possibility to follow the development of a criterion from a lower to a higher level, and vice versa, thereby providing the opportunity to the user to follow the positive, and negative development. Furthermore, the possibility to check the presence of multiple criteria at the same time is present, since all criteria need to be checked when assessing the readiness. Finally, by including the option to follow the development of a criterion over time. In the NRL –indicator the criterion is not present on the one day, and absent on the following day, but develops over time. This provides a more elaborate view of the socio –technical development.

The methodology, thereby, facilitates the indication of the readiness of a network of actors on a numerical scale. The NRL –indicator asks for repetitive use by an individual actor or within the network. If the methodology is used repetitively, the user obtains a temporary insight into the status and should reason on the steps that have to be taken to stimulate the socio –technical development.

7.2 Recommendations

The NRL –indicator is a first proposal of a new methodology. Future research, and future applications of the methodology must prove its value, and its limitations. Some recommendations on NRL –indicator research might prove to be a first step. The NRL-indicator uses 16 criteria of a collaboration in a network of actors, used to determine the level of development of a network. Future research could be conducted into whether criteria need to be added, or whether some criteria need to be removed from the NRL -indicator, in order to make the tool applicable to different types of networks.

Besides this, the NRL -indicator does not mention the pre -conditions of collaboration, that were determined based on the outcomes of the interviews. Also the product and process factors are not included. These can be added in a future research to provide a more elaborate version of the NRL -indicator

As a final recommendation, the NRL -indicator includes three characteristics of collaboration in a network; the dynamic character, same time presence of criteria, and the development of criterion over time, to make the tool more realistic. The NRL -indicator is, however, a first draft of a management tool, and needs to be validated in practical cases. A first research, and application of the tool could be to use the tool in a project that spans multiple months, or at least a longer period of time. The NRL -indicator could be used in this project, to assess the level of development of the network on a monthly basis, to check whether the tool is applicable. The outcomes of the research could function as a validation, but also an insight into potential adaptations that have to be made to the methodology.

Thereby, the NRL –indicator is a first draft of a methodology that can be applied in multiple networks of actors. The proposal hopefully adds to the research fields of network management, and collaboration in socio –technical systems. In order to understand its contribution, but most of all its value, future studies should focus on the validation, and adaptation of the methodology by using it in practical cases. The results could lead to a whole new theory on how collaboration in networks could be structured, and facilitated.

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Appendix

The Appendices are not included in this paper, due to the sheer size of the tables. For the following Appendices, I would like to refer to the main thesis. The different tables can be found in the thesis in full size:

Appendix A the tables can be found in paragraph 3.3

Appendix B.1 the table be found in paragraph 5.2.5
Appendix B.2 the table can be found in paragraph 5.3.2
Appendix B.3 the table can be found in paragraph 5.4.3