

# Change of owner, change of plans

*A METHOD TO COMPARE DIFFERENT OWNERSHIP MODELS OF A SYSTEM, APPLIED TO A  
STEAM CASE*

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## Preface

Before you lies the last report for the graduation of the master education: System engineering, policy analysis and management. This final master thesis has not been the easiest part of the education, but nonetheless has it been a broadening experience for me. I have learned a lot, about myself and many other things.

I would like to thank my committee. Rob Stikkelman, Paulien Herder, Daniël Scholten and Guy Konings. I would like to thank Stedin for the opportunity and input during the research. Thank you Rob for the feedback and restructuring tips. You have helped me on improving my weak points. Also I would like to thank Jan, Jorick, Tim and Ronald. You guys all provided feedback and structure when it was necessary.

As last I want to thank my girlfriend Lisette. You helped through the whole research and knew what I needed. Without you, I would not have been able to execute this. All support has been greatly appreciated.



## Summary

The effect of renewables is becoming noticeable in the electricity system. Cheap peak electricity provides an opportunity for the industrial sector. Different projects are set up to make use of the cheap peak electricity. Stedin wishes to participate in a steam system, but is not sure on the optimal way of conducting business. The question is whether there is a better way to design a technical and economical sound system, when taking the ownership setting into account. This led to the following question from Stedin:

“Is the ownership setting of the steam system the limiting factor for successful projects, as the projects seem technically and economically feasible?”

Ownership is expected to have influence on these projects. However, in order to identify this influence of ownership in a system, a methodology needs to be developed. For this the institutional aspect needed to be integrated with the technological aspect. This research has created a method (ROA) to assess the effects of ownership in these kind of socio technical systems. This was based on the following research question:

*How to compare ownership settings of a system, by creating a method?*

The focus lies on the integration of the technical system with an ownership setting. This led to the creation of a three phase method. Within this method, the first phase focusses on designing, the second phase focusses on valuing and the third phase focusses on interpreting.

To reach this method, Literature on infrastructures and risks was consulted. There was no literature that compared systems with an ownership aspect. A literature study has been done to investigate other methods for integration of technical and ownership aspects (Correa-Henao, Yusta, & Lacal-Arántegui, 2013; Gómez, Sánchez-Silva, & Dueñas-Osorio, 2014). No method was found that had all aspects in common with the goal of this method. However, the phase structure from other methods found in literature is used in the created method. The method consists of three phases. The first phase focusses on designing, the second phase focusses on assessing and the third phase focusses on interpreting. The method will be referred to as: The Risk Ownership Assessment.

The first phase focusses on the design of the system and its components. The goal of this phase is to create ownership configurations which can be used in the second phase. This is done in three techniques. The first technique focusses on defining the technical system and creating system boundaries. After the first technique, the inputs, outputs, boundaries and function of the system are clear. The second technique focusses on the breakdown of the system. The system is broken down into components, which can each be owned by only one party. After the system is broken down, the third and last technique of the first phases focusses on the creation of ownership configurations.

The second phase focusses on valuing the different ownership configurations. The configurations are assessed so that they can be compared in the last phase. The valuing of the ownership configurations is done through risks. This is done in two techniques: The risk identification and risk assessment. In the risk identification, risks are identified at the level of the different components. The risks are coupled to the components; the ownership of the component is taken into account here. The second technique focusses on valuing the risks. This is done with use of the ATOM method, where the likelihood and impact determined the risk scores of the risks. After all configurations are assessed, ROA moves on to the last phase.

The third and last phase focusses on the interpretation of the configurations of the previous phase. This phase consists of two techniques: the interpretation of each individual ownership configuration and the comparison between the ownership configurations. The first technique is the analysis of each ownership configuration individually. The first thing done in this phase is the reduction of amount of risks per component. Only the three highest scoring risks are used per component. This technique continues by identifying different information from the configurations. The total risk scores, owner risk score, component risk scores and biggest risks are identified and set up for the last technique. In the last technique the configuration information from the previous technique is set next to each other. Conclusions are drawn on the different aspects of the system. This leads to an overall conclusion of the system.

The Risk ownership Assessment has been applied on a case study. This case study is used to improve the method as well as to validate the results. The case study focused on linking a gas boiler and an electrical boiler both providing steam in a system in the Port of Rotterdam area. The case study focused on a steam system in the port of Rotterdam. Two ownership configurations were compared. The results showed that the case study output showed difference in the two configurations, and qualitative information could be drawn from the results.

The case study showed that the method was able to assess effects of different ownership configurations and provide qualitative data on the matter. As it turned out, the natural gas boiler carries a bigger risk than the electrical boiler, since the CO<sub>2</sub> price is uncertain in the future. The distribution system carries a relatively large risk. It implicates that this should lead to more revenues for the distribution. A system with a large dominating party is not beneficial for the less dominating parties. However, the whole system does not carry much more risk than the other configuration.

ROA was evaluated on four points: degrees of freedom, ownership, speed and users. From the evaluation comes forward that the method fulfils its demands, but at this time only can be executed by experts. The main focus lies on making the method more user friendly. The goal is to create a method that can be used, therefore the usability should be focused on in possible next techniques.

The research developed the Risk Ownership Assessment that compares ownership settings of a technical system. The method is used on a case study of a steam system. From the case study, several findings on both the method as well as the case study were identified. The recommendations focus mainly on making the method more user-friendly.

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# 1. Introduction

## 1.1 An effect of renewable energy

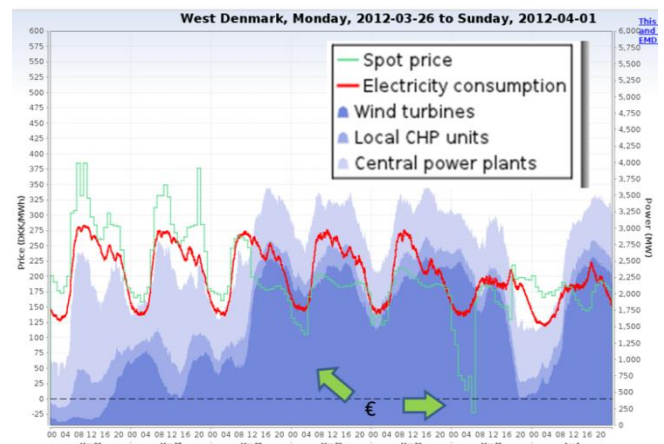
Global warming is booming. Because greenhouse gases are being emitted in the atmosphere, the temperature in the world is rising. The problem is that it is not one party that is the problem. Different parties from different sectors contribute to this problem.

One of the major contributing sectors is the electricity sector. The electricity sector is mainly based on conventional power plants that burn fossil fuels to generate electricity. This results in high levels of emission. These power plants are becoming more controversial because of the increased attention to global warming.

The electricity sector responds to this movement by investing more in renewable electricity. Windturbines and solar panels are the main focus in these renewable projects. This leads to a higher share of renewable electricity in the electricity mix. The problem with renewable electricity is that it cannot be controlled. Since the companies invest more in these forms of renewable electricity, renewables will have a higher share in the energy mix.

A higher percentage of renewable energy will have effects on the electricity market. The electricity market is designed/organized as a demand based market. This means that the electricity supply responds to the electricity demand. With renewable electricity, the supply cannot be controlled. The question is what kind of effect this has on the electricity market.

Denmark is a country which already has a high rate of renewable electricity in their electricity mix. Denmark has so much renewables, that at certain point in time, too much electricity is available on the market. This resulted in a very low to negative energy price for certain periods of time(EMD, 2014). These energy fluctuations combined with negative prices are shown in Figure 1. These circumstances can be expected to be present more often when the renewable energy share will rise in the energy mix.



**Figure 1 Electricity Demand and Supply in West Denmark(EMD, 2014)**

## 1.2 A fluctuating electricity price and the industry

The electricity price will fluctuate more in the future due to renewable energy. Two aspects of fluctuation need to be specified. The first aspect is the direction of a fluctuating electricity price. The second aspect addresses the parties that can make use of the opportunities that arise from fluctuations.

A fluctuating electricity price can go in two directions. The first direction is a high electricity price for a short time, and the second direction is a low price for a short time. The high price is an opportunity on the production side of the market. The electricity producer can respond to the higher price and has the opportunity to make an extra profit in this situation. The other opportunity is a low electricity price for a short period of time. The consumer side can respond to this cheap electricity. With a quick response to the cheap electricity, savings can be made. The short periods of low electricity prices lead to the product of cheap peak electricity. This cheap peak electricity is an opportunity for parties. This research focuses on cheap peak electricity.

The second aspect is how to use this cheap electricity. Two main user types can be identified as potential users: residential users and industry users. The question is on which party should be focussed. For this is looked into drives of the different parties. With the residential consumers, awareness is an important factor (Hubert & Grijalva, 2011). The industry is more interested in economic gain with the use of cheap peak electricity. The consumers are less interested in the direct economic gains, whereas the industry has a more direct motivation to make use of cheap peak electricity.

The focus for this research lies on the industry. The companies with a flexible process will be more likely to make use of the cheap peak electricity. Larger installations can contribute to the use of cheap peak electricity. The industry is mainly driven by economic factors. There are already several possibilities for industries to participate in cheap peak electricity.

## 1.3 Research basis

The research focus lies on cheap electricity and its opportunities for industrial users. The research done for this thesis is based on an existing report on these topics and the recommendations that came from it (Stikkelman, 2014). The report focused on the use of the cheap peak electricity and was conducted in combination with the DSO Stedin. Stedin saw an opportunity to use cheap energy and wondered how to develop this opportunity further. The next section discusses the findings of the report. In continuation of the previous report Stedin will also be involved in this research. Stedin's development wishes for this new research will be explained afterwards.

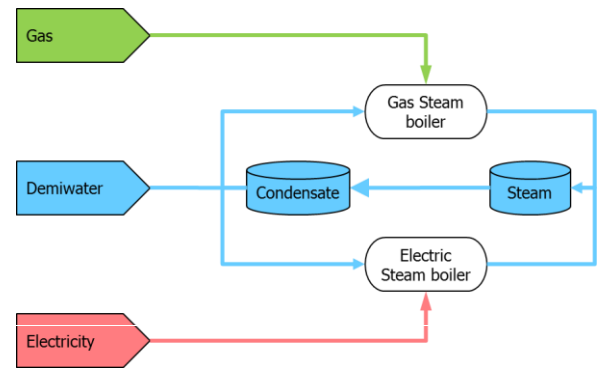
### Previous research

Much research already has been done into the use of the cheap electricity that is caused by the increase of renewable energy. Different options like peak shaving, dynamic pricing ((SBC), 2004; Jang, Eom, Kim, & Rho, 2015), to use or store the cheap electricity (Sovacool, 2009). One of these reports has been made in cooperation with Stedin. From the report of Stikkelman (2014), a steam system looks like a good possibility to develop for the future.

The report "Converting excess wind power into power valuable products"(Stikkelman, 2014) discusses what the demands are for such technologies. The primary aim of that desk study is to find ways to "reduce the energy costs for production by making use of fluctuations in electricity supply". The results are that certain technologies to capture cheap peak electricity are technically and economically feasible. However, the institutional setting can provide a problem for the implementation of these technologies.

The report compares different techniques based on marginal costs, investment costs and response time. Tirthy technologies were compared of which two technologies were promising. These technologies received a further analysis on feasibility. The first technology is a dual resource fired steam system, which makes use of a natural gas boiler and an electrical boiler. The second technology was the production of methanol from hydrogen. The hydrogen would be created through an electrolyser. The dual resource fires steam system showed the most potential, so further research is required.

The most promising technology was a steam system which operates on both natural gas as electricity. The idea behind the system is that an electrical boiler is build next to an existing gas boiler and steam circuit. The system allows to switch between steam from electricity and steam from natural gas, thus letting the operator to have a financial benefit by choosing the cheapest resource (Stikkelman, 2014). With the fluctuating electricity price, this could become a viable case. A steam system would look like the system displayed in figure 2.



**Figure 2: Steam system in port of Rotterdam(Stikkelman, 2014)**

The report “Converting excess wind power into power valuable products” (Stikkelman, 2014) did an economic assessment on the dual resource fired steam system. From the economic assessment comes forward that the steam system has little expected problems to be implemented. The value of steam is relatively high and the investment costs are relatively low. This leads to a low financial risk.

The institutional analysis focuses on the problems expected with a steam system from a technical, economic, commercial, and organizational and a political point of view. Explanations are given for certain values in the risk analysis, and the main issues that are expected. The main aspects that are prone to the problem are the electricity price, as well as the contracts that should be closed with this system. About the contract management is told that there are still many different options on how this system can be designed.

The analyses have provided useful information, but a more thorough analysis is required. From the report comes forward that the technological risks are present, but not that big. Therefore, the focus should lie on institutional risks in future research. Since a steam network integrates both the natural gas infrastructure as well as the electricity infrastructure, several components can be owned by different parties. In the end a network will be created where several components can have a different owner, whereas other components have limited options available for different owners

The main issue that comes forward form the report is that a steam system has a lot of potential, .but needs to be further analysed for a better view. The problems are expected to lie on institutional ground. The next section discusses how Stedin thinks this could be filled in.

## Stedin and ownership

The research is conducted for the department of New Business Development(NBD) of Stedin. NBD focusses on new developments in the electricity market. The use of an electrical boiler combined with a gas boiler for the capture of peak electricity is considered in their domain. The goal of NBD is to own and operate the transport in such a system.

One of the main problems for NBD is that the success rate of the projects is low. Many projects fail for different reasons. Most of the time, the problems lies with the negotiations and less on the feasibility of the project. NBD looks into the case to improve the success rate of these projects.

The question from NBD is whether their way of conducting business is the best one. The usual approach is that NBD owns and operated the pipelines/cables. There are other ways to design such a system with owners. The goal of the research is to provide insight on the advantages or disadvantages of other configurations. The plan is to compare different **ownership configurations** with each other.

The first question is what ownership exactly is. Ownership is a small aspect of the institutional spectrum. IN a system, the discussion will go on what components will be owned by which owners. The ownership of components can be related to the property rights that come with the owning of components. Therefore, ownership is treated with the same interest as property rights. The report used literature on property rights, but will continue using ownership as focus of the research.

A literature review on property rights has been done by Furubotn and Pejovich(1972). The review discusses that property rights are broader than the term suggests. The rights that come with property determine how costs and rewards are allocated among the participants in an organisation. The review shows that property rights and ownership are effected through contracting(Furubotn & Pejovich, 1972). The review states that the behaviour of organisations will depend on the nature of these contracts.

The assumption is that this will work the same for behaviour of participants in a system. Contract negotiations are expected to be a factor in project failures. Therefore, contracts are in the interest of Stedin. Insight in property rights that come with ownership is key in contract negotiations. Therefore ownership is used as main variable in the systems.

The contracts are results of the risks that are in the system. The goal is to capture the risks of a system into contracts with different parties. These contracts are in the interest of Stedin. NBD wishes to increase the success rate of the projects they enter, and the contract negotiations are expected to be an aspects of the project failures. The insight in the contracts is related to the insight in property rights and ownership. Therefore ownership is used as main variable in the systems.

The second choice is the use of ownership configurations. For this is looked at how ownership can be compared. A distinction is made between the technical system and the ownership of the technical system. The goal is to keep the technical system the same, so that the effects of ownership can be compared to each other. By isolating the ownership setting from the technical system, the value of ownership can be identified.

The steam project from the report "Converting excess wind power into power valuable products"(Stikkelman, 2014), as explained in the previous section, can provide the base for a good case study. Stedin cooperated with the report and is interested in the development of a dual resource fired steam system. A method will be developed with the case study to provide insight in different ownership configurations.

## 1.4 Problem statement

The previous sections show that the energy landscape is changing. The New Business Development department of Stedin wishes to participate in this change, but does not know if their way of conducting business is the best one. This is why New Business Development wishes to have more insight in the different ways of designing a system with ownership configurations. The most important question, from the perspective of their business was framed as follows:

“Is the ownership setting of the steam system the limiting factor for successful projects, as the projects seem technically and economically feasible?”

The question asked by NBD has three main aspects: The system definition, ownership configuration and how they interact with each other. The aspects will be further elaborated upon in the next chapter.

This thesis aims to use a scientific approach that contributes to answering the question as asked by NBD at Stedin. For this reason the question asked by Stedin is used to define a more general problem statement:

“How can the ownership setting of the steam system affect the success chance/risks related/viability of the overall system?”

An answer on this question is aimed to be found by creating a new method that allows comparing different possible ownership setups. This approach will be outlined in the following chapters:

The **second chapter** of the research focusses on how to approach the research. This is done through a literature study on different frameworks. The next section shows how the structure is translated into research questions. The following **chapters 3,4 and 5** show how the method is built with the use of the case study. With a complete framework, the framework is tested with an evaluation. **Chapter 7** draws conclusions from the framework to see if the framework functions as intended. **Chapter 8** consists of a research discussion and a validation of the techniques that were used for the research.

## 2. Research structure

### 2.1 Problem analysis.

The problem analysis focuses on the main aspects that have come forward in the problem statement. This section shows what should be expected with the different aspect of the problem statement: technically and economically sound projects, ownership and the limiting aspect. The next section tells how these problems are addressed.

#### *Technically and economically sound projects*

The first aspect is what a “technically and economically sound project” looks like. The term technologically and economically sound, means that there will be no main issues in the technical and economic viability of the project. The techniques that are used are proven, and the business case of the project is positive. The focus lies on different ways of conducting business.

These systems consist of different components. The system of Figure 2 in the previous chapter is expected to have three main components: the electrical boiler, the natural gas boiler and a party that uses the steam. These components will all have their own function. The level on which the system is looked upon is also important. The system could be looked from a higher aggregation level, which would result in a system of only one component, but also each component could be split up into smaller components.

#### *Ownership*

The level of aggregation of the system leads to the second aspect, which is the ownership of the different components. The system is still described on a very broad level, where the components of the system are quite big. If other aspects such as transport and operation are taken into account, the system will have more components and these components can be owned by different parties.

This leads to the question on how the differences between the ownership of the components can be measured. If we look at what the difference is with different ownership settings, it can be thought of that the investment of a party in the system is different with the different ownership setting. The amount of money invested differs per configuration per party. Investments are coupled with risk. This shows that risks are interesting to look at with the different ownership settings.

#### *Limiting setting*

One of the other main questions is why ownership setting usually do not change. Why is this situation an opportunity when comparing it with other systems? This is because the rules and contract for such a system lock the system in place. Changes in the system are very hard and very expensive. This usually leads to the analysis that it is not worth it to change the system.

However, when the opportunity arises to create a new system, it should be noted that the goal is to organise the system optimally. The opportunity should be used to find out what the advantages and disadvantages are of different ownership configurations. Since it is not clear what the differences are in the different ownership settings and the expected effects on the performance of the system.

The opportunity provides a window for new business. It is not clear on how this project will have a bigger chance for success. Different ownership setting need to be compared with each other. This leads to a problem which focusses on the risk of the different ownership settings of a system. The research will combine a technical system with ownership settings and risks. For this a method is created.

A method will be created for assess the ownership setting of the technical system. Before this can be done, the scope of the research is identified. Also a literature review is done on how such a problem should be handled. The scope and literature review will eventually lead to the research question.

## 2.2 Scope

During this research, assumptions are made when analysing the problem statement. This narrows down the research to avoid that an infinite number of aspects have to be taken into account.

As introduced before, one of the main assumptions is that the projects are technological and economically sound. This means that it is expected that no real problems will occur with the implementations of these projects. The fact that this research is done is because the business case has been found positive. It also does not lie in the scope that certain technologies will provide problems if they work together with other technologies.

The second boundary is ownership. Ownership is only a small part of institutions. We expect that with ownership alone, differences can be found in the different ownership settings. The goal of this research is to find out if ownership alone can bring such differences forward, so no other institutional aspects is taken into account.

The third and last aspect is Stedin. The research is conducted for Stedin and thus the case study will also focus on the possibilities for Stedin. This also means that the recommendations focus on improvements for research as well as the possibilities that have come forward for Stedin.

## 2.3 Approach on research structure

The problem analysis shows that a technical system with different components, different ownership settings and the valuing of these systems through risks are combined. For this is a literature study conducted. For the research have different online databases been searched (science direct, scopus, google scholar). In the databases has been looked for keywords such as: risk, infrastructure, ownership and complex.

With the research, no articles have been found which handle the problem exactly as it is explained in the problem analysis. Therefore the choice is made to create a new method. The articles found are to a large extent applicable to the problem, though. The structure of the research in the articles can be used for the creation of a method. Three articles on different subjects are reviewed. In the following sections an explanation of the relevant articles and their usability is provided.

### 2.3.1 Article 1: CoDAN Framework.

The article “An applied complex systems framework for risk-based decision-making in infrastructure engineering” provides solid connection points for a framework focused on risks of infrastructures. (Gómez et al., 2014). The article introduces a framework of Complex Distributed Agent Networks (CoDAN), which assesses the risks of an infrastructure through an agent based model. This is done in three different modules, which are discussed below.

The CoDAN framework uses three modules to assess the full framework. These are called the modelling, assessment and intervention module. Within the modules the framework uses algorithms to assess the risks in an agent based model. This leads to the modelling of the system in the first module. The modelling module focusses on the decomposition of the infrastructure hierarchically into clusters. The framework focuses on the clustering of the components of the network. The second module is the assessment module. This module uses the clusters to compute indicators of performance and risks. The performance of the clusters is ranked in a two-dimensional way. They are ranked on nominal performance and risk. The last module of the framework is the intervention

module. In this module, the input of the assessment module is used and interpreted. The information is used for decision support.

What can be interpreted from this article is that three phases can be identified for the model study. The framework that has been set up has different focuses than this research, but this study can use a similar set up. The three phases: modelling, assessing and intervention are useful in the creation of a new framework to look at the ownership problem of a steam system. The specific techniques that are used can be replaced by other techniques that will connect better to the research problem.

### 2.3.2 Article 2: Interconnected risk maps.

The Article “using interconnected risk maps to assess the threats faced by electricity infrastructures” focuses on a special risk analysis with an electrical infrastructure (Correa-Henao et al., 2013). The paper focuses on the risk identification and risk assessment of an electricity infrastructure. The framework that is set up uses six steps:

1. Establishment of safety goals
2. Identification of resources and risks
3. Assessment of risks
4. Prioritization of actions
5. Implementation of protection programs
6. Measurement of effectiveness

Only the first four steps are discussed in the paper. The last two steps require the implementation in the project and will use the information gained from the risks assessment. This shows that the framework is not a framework that can fully be executed through research alone.

The establishing of safety goals can be interpreted as the problem definition of a project. The focus of the research in the paper lies with the resources that can be used by enterprises in the electricity sector to reduce the risks. The risk identification explains that there are several ways to identify the risks for such a risk assessment. Risk maps represent the interrelations between the various risks. According to the article risk maps are a good way to identify risks. Several popular risk maps are: COSO audit maps, holistic schemes, radar maps and enterprise risk maps.

The risks, identified through a risk map, are used in a component risk assessment. This is a risk analysis where the effects of risks will be divided into different components. This shows that risks will be assessed on different effects. Risks that will have effect on different categories will have a higher score. This also leads to the prioritizing of actions, where the risks with a bigger score will require more extensive measure than smaller risks.

From this paper can be concluded that the effects of risks can be divided into different categories. The idea of categorizing risks into different categories can provide extra information in the interpretation of risks. The article uses categories to underpin the values that come forward from the risks assessment, but this categorization can also be used to provide more insight in the differences between risks of different parties. This article uses the three phases of defining, assessing and supporting the decision. The only derivation is that the three phases are divided into six phases with different phase titles.

### 2.3.3 Article 3: Systems thinking and network modelling

The third article is the 17<sup>th</sup> chapter of the book “Handbook of seismic risk analysis on management of civil infrastructure systems” (Sánchez-Silva & Gómez, 2013). The chapter discusses a risk assessment on an infrastructural project. The framework in this research focuses on complex interactions between the different components on a structural project. The focus lies on the systems and what a system is in itself, and also in the interactions that occur in such a system.

This framework also exists of three phases. The first phase is a graph theory that is used to model the system. In the next step, through hierarchical relations and clusters, the system is structured. The second phase assesses the risks. The risks are assessed on three different categories: reliability, vulnerability and damage propagation. These three aspects are according to the author the most applicable techniques that are necessary for an effective risk assessment in the research. The last phase is the decision support, in which linear programming and hierarchical based optimization are the techniques used to optimize the resource allocation for the decision makers.

### 2.3.4 Articles conclusion: Three phases

What can be drawn from this literature is that the three phases seem to be a recurring strategy. While the techniques differ in the other articles, there is still the model, risk assessment and decision support phase. The question that arises is if these techniques are fitting for the goal of the framework. Since the article focuses on a more technical design than this research focuses on, these techniques will not fit into the framework.

With the risks of infrastructures, different scientific frameworks follow the same line with the use of three steps (Correa-Henao et al., 2013; Gómez et al., 2014; Sánchez-Silva & Gómez, 2013). These three steps can be described as system approach, risk assessment and the supporting of a decision. The steps are called differently in the different literature. In this research they will be called: **Designing, valuing and interpreting**. The literature also pays different levels of attention to the different steps, but the different articles all follow the three steps.

The three phases are directly translated to this research. The three phases will provide the backbone on how to treat the problem of different ownership settings. The first phase focuses on the system breakdown. This can be done very simple by using an established model of an infrastructure or a system that can be logically broken down. The second phase will consist of a risk analysis in which the risks are identified as well as analysed. The third and last phase will compare the different configurations and conclude the results. These activities can be combined into a comprehensive method.

## 2.4 Research question and sub questions.

In the previous sections was shown that there is enough scientific basis for setting up a method to compare ownership configurations in a technical infrastructure setting. The aim of this research is to create a method that is applicable to the problem statement. This leads to the following research question:

How to compare ownership settings of a system, by creating a method?

### Sub questions

The research aims to provide insight in different ownership configurations for a steam system. This is done by developing a method for the comparison of these ownership configurations. The question was how such a problem should be handled. This resulted in a literature study on comparable problems in section 2.3. From the literature research comes forward that the frameworks analysed does not fit directly for this research, but that the same structure will be used. Three phases are used in the execution of this method. The three phases focus on designing, valuing and comparing the different ownership configurations. These three phases provide the base for the different sub-questions.

The first sub-question focuses on the first phase: design. In this phase, the focus lies on designing different ownership configurations. These configurations need to integrate the technical system with the ownership setting. Multiple ownership configurations should be ready for the second phase. This leads to the first research sub-question: *What does the first phase in the developed method look like, with the goal of creating ownership configurations?*

The second phase focusses on valuing the different ownership configurations. The ownership configurations that are created in the first phase need to be measured. By measuring the ownership configurations, differences between the performances of the configurations come forward. The research sub-question is: *What does the second phase in the developed method look like, with the goal of valuing ownership configurations?*

The third and last phase focuses on comparing the ownership configurations. The goal of this phase in to extract the useful information of the different ownership configurations and draw conclusions and give recommendations for the client of the method. This lead to the third research sub-question: *What does the third phase in the developed method look like, with the goal of comparing ownership configurations?*

The comparison method needs to be validated. This is done through a case study. The results of the case study can be combined with an evaluation of the method. This leads to the sub- question: *How valid is the method?*

The case study itself will also hold information for Stedin. The information of the case study can is analysed and used for Stedin. This leads to the sub- question: *What are the results of the case study?*

The last question is more based on the future use of the method. The created method will be expected to fulfil its demands and compare ownership configurations of a system. The question is how this method will be used in the future. This leads to the question: *Which measures can improve the use of the method in the future?*

## 2.5 Research framework

The method focuses on the integration of ownership settings in a technical system. This method is named the **Risk Ownership Assessment (ROA)**. This name is based on the fact that the method uses risks to assess different ownership settings. The next section discusses what the research framework is. The framework is shown in figure X and can be seen as the backbone of the research.

In the framework are four inputs used for the information. A literature review is conducted to provide the structure for ROA. The three phases came forward from this literature review. The different phases only give a broad description on the task of these phases, so techniques need to be selected. A desk study, combined with more literature reviews are used to fill the different phases with the techniques. After all the techniques are selected or developed. ROA can be seen in its concept version.

While ROA is developed, the case study will be conducted at the same time. The case study provides practical implications on ROA. The techniques of ROA will all be submitted to the case study, and provide a first test for the techniques. The expertise of Stedin is used through expert interviews as well as a workshop.

After the full ROA method is developed and is tested through a case study, the method will be evaluated. What does ROA actually do in the end and does it function according to plan. Also possible developments can be pointed out. The conclusions on the method and case study will follow afterwards.

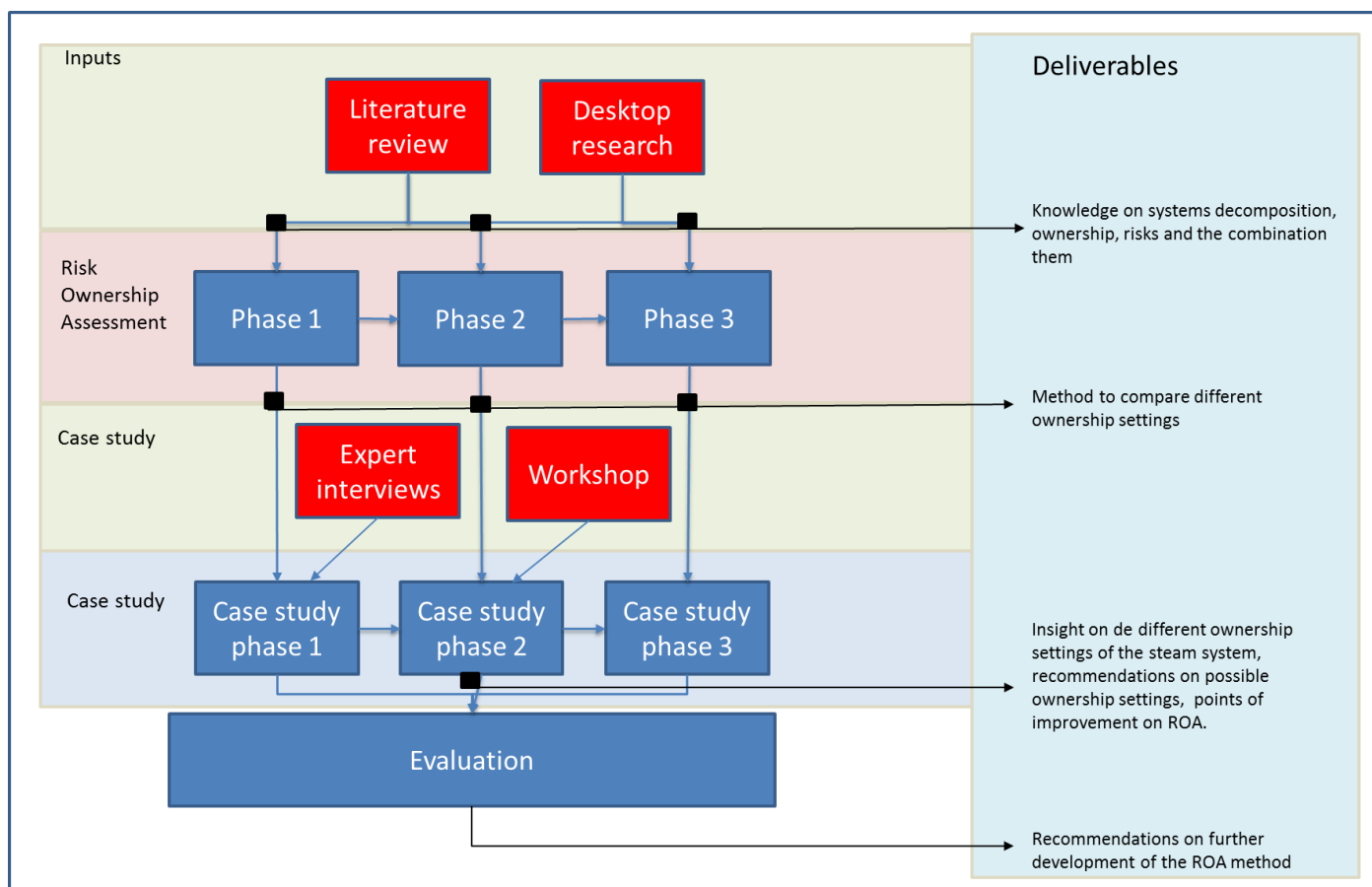


Figure 4: Research framework

### 3. Developing Phase 1: Creating ownership configurations

The previous chapter shows that the first phase focuses on the design of different ownership configurations. This chapter shows how the ownership configurations are created. First the structure on how to execute the phase is discussed. The structure is then worked out in different techniques.

#### 3.1 Structure of Phase 1

In this phase is the design of the ownership configuration the subject. The question answered in this chapter is: What does the first phase in the developed method look like, with the goal of creating ownership configurations?

The first question is what an ownership configuration looks like. No research has been found that works with ownership configurations. So the focus here lies on the designing aspect. The integration of the ownership aspects is the scientific contribution. Several designing techniques are analysed. The comparison was done with flow diagrams, interviews and the TIP design technique (Bots & Van Daalen, 2012). For this is the base used of TIP. TIP is a design method that tells that socio-technical systems consist out of a technical and institutional part (TI). The P in TIP stands for process and tells how the system is implemented.

What is used from the TIP framework is that the system can be split up in a technical and institutional aspect. In this research, the institutional aspect is interpreted as the ownership aspect. There is also a big difference with the TIP design. Whereas the TIP design focuses on the development of a system from two aspects (technical and institutional) of the system, is it in this method more logical to first provide a system base, and then add the technical and ownership aspect. This leads to three techniques that can be used in the first phase.

The first phase consists of three techniques. The first technique is to **define the system** and set system boundaries. This will provide the base for the technical system and ownership setting. The second step **breaks down the technical system into components**. This is the technical base for the integration with ownership setting. Since the research focuses on the comparison of ownership settings it is logical that the ownership settings should be the variable factor in the system. This leads to the technical system to be locked in. The ownership settings will change whereas the technical system stays the same. The third and last technique is to **create the ownership configurations**. A method needs to be found to combine the institutional setting with the technical system. These ownership configurations are valued in phase 2 and compared in phase 3.

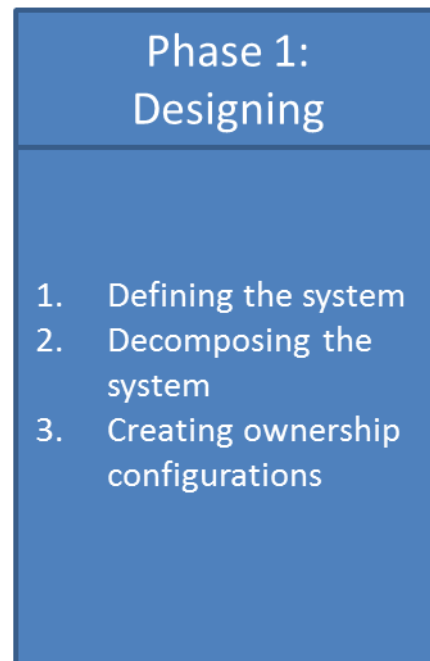


Figure 5: Summary phase 1

### 3.2 Techniques phase 1

This chapter consists of three techniques. The techniques are explained in the following way:

1. First is the theory and reasoning behind the technique explained. How the technique should be handled.
2. Next is the conceptual design of the technique discussed. How is the technique executed
3. The third section discusses the case study. The technique is applied to the case study to test the technique as well as work on the case study
4. The last point is that the findings of the applied technique to the case study are discussed. What were problems that occurred when executing the technique?

#### 3.2.1 Technique 1: Defining integrated system

The first technique is to define the system. This is what the rest of the ROA is based upon. The goal of this technique is that the system should be clear. There are two main aspects that are central to the definitions of the system. The main aspect is the function of the system. The second large aspect is the system boundaries.

##### *Theory*

The system definition is an aspect that is closely related to an engineering design. The consulted literature is "Engineering design, a project based introduction" (Dym, Little, Orwin, & Spjut, 2004). This book covers the aspect of designing an engineering system, which fit in the view of the first technique of ROA. The literature provides a prescriptive model of the design process. This 15 step model supports the view on a system design. Since the model is used on engineering design, the model will not be applicable on all the steps. The phase in which the technical system and institutional aspect are integrated will divert ROA from the design model. The first 4 steps fall under the problem definition, these are listed below:

1. Clarify objectives
2. Establish metrics for objectives
3. Identify constraints
4. Revise clients problem statement

The systems used in ROA do not need to be technically designed. This has been done before ROA is started. This is why ROA focuses on "technical and economical sound" projects. The focus in this step is to use the information that already is available for the ROA design. The technical system is used as a base for the ownership, thus the technical design is needed. The four steps listed above show a possible structure for the system definition. Since the system is already designed on a technical aspect. The problem statement does not have to be changed. This means that the fourth step is not necessary.

The objective of the system is central in the first technique. What should the system perform? This can be interpreted to the system function. This system function can have objectives. However, the system is already technically designed, thus no objectives need to be set up for the technical system. So the first two steps are translated into a system function.

The third step is the identification of the constraints. For ROA is it useful to identify the boundaries of the system. Since it is expected that the system will interact with entities outside the system boundaries, inputs and outputs need to be added to show what the system requires to be able to perform its tasks.

The system definitions literature shows that there are four aspects that need to be identified in this technique. The system function shows what the task is of the system. The boundaries show where the system function ends. The input and the outputs shows what the system needs from outside the system boundaries to function.

### Conceptual design

The first part of system identification is to make the boundaries of the system clear. Both the project objective as well as the constraints of the project must be clear (Dym et al., 2004). This step can require different levels of effort for different projects. The goal is to have a clear system with bounds and constraints.

The first step is to identify what the exact function is of the system. For this a block diagram is used (Figure 6). A simple black box is the result of the technique with all the inflows and outflows of the system. The inflows and outflows are all the physical and relevant flows that are connected to the system. The output is a clear scope of the system. The output is shown in Figure 6: Visualisation phase 1 technique 1

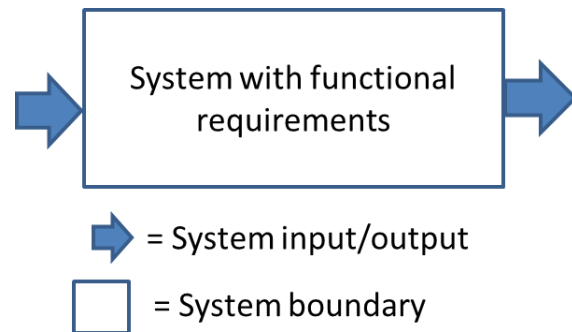


Figure 6: Visualisation phase 1 technique 1

### Case study

From the previous sections comes forward that the system is a steam system. The case study focusses on a system that uses the fluctuating electricity price for a possible cheaper production of steam.

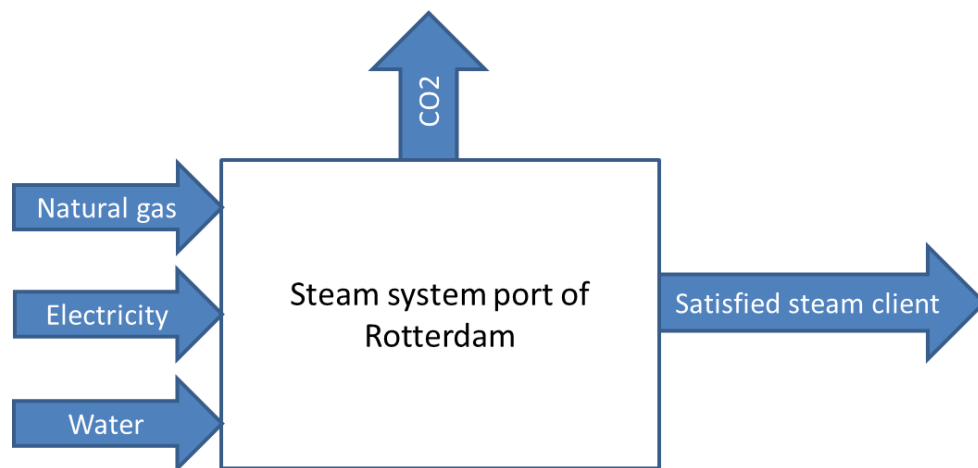
The first aspect identified is the system definition. The system will transform water into steam with the use of electricity and gas. The resources are used for the transforming of water into steam. The system delivers the steam to clients. The clients use the steam and return the condensate.

The system boundaries are identified. On the input side of the system, the border can be drawn where the electricity and natural gas enters the system. These aspects will be taken into account, but will not be part of the system itself. Also the clients are a significant aspect of the system. Therefore the clients are taken into the system itself. This also leads to a less tangible system output, the client's needs to be satisfied with the steam that is delivered.

Water will be an input for the system, but this is to be expected to be a minor aspects of the network. The water used will be recycled, and new water will be imported in the system. But the costs of the water are very small compared to the costs of the electricity and natural gas. Still will this used in the system and should not be left out.

There are two output of the system. CO<sub>2</sub> is emitted through the burning of gas. For this will be CO<sub>2</sub> permits necessary. The other output is satisfied steam clients. This means that the steam clients will be part of the system and the steam itself is not the output of the system.

This information combines in to a system shown in Figure 7: Output phase 1, technique 1 of the case study. In the system it is clear that the three inputs are characteristic for the system. The inputs show that the main boundary is the resources entering the system. The transformation of water into steam and the delivery are the main aspects of the system. The CO<sub>2</sub> output is a by-product of the burning of gas. The next step is to look how the system can be decomposed into different components for the ownership configurations.



**Figure 7: Output phase 1, technique 1 of the case study**

### *Findings technique 1*

The first technique did not identify new problems in the development of ROA. The technique is simple and logical. It could even be said that it is almost redundant. However, when cooperating with multiple people and showing your research. It is worth is to have all the parties on the same page. Therefor the first technique has its main value on showing everyone what the system exactly is.

Another finding of the first technique is that the technique itself is quite simple, but it has quite a large output. It is clear that the system is not as easily defined as expected by the technique. This shows that the system definition is not that clear as in the explained technique.

The system definition is a solid base for Stedin for the further steps. The system is derived from the report “Converting excess wind power into power valuable products”(Stikkelman, 2014). In this report, the steam system is discussed quite thoroughly. Since Stedin was involved in the report, this step was more a calibration step if the system has not changed. No big changes have been applied to the system in this technique.

### **3.2.2 Technique 2: Decomposing technical system**

The second technique of ROA consists of decomposing the complete system into components. By cutting the system up into components, the system will be able to perform the same tasks, only there is more insight in the different components of the system.

### *Theory*

The goal in decomposition technique is to identify the technical system and how to translate the ownership setting. Appendix 1 discusses how systems thinking could be used for the creation of the technical system. The technical system will be built upon the system created in the first phase. So the system is already defined. The system will be cut up into different components. In the conclusion of the appendix, there are two main aspects that are central for the creation of the correct technical system:

1. The system needs to be hierarchically decomposed. The system needs to have a main function, which can be partitioned into sub functions.
2. In a functional analysis, the flows between the different components need to be represented. These flows can contain information or physical items.

Breaking down a system is common in the technical world (Canteach, 1996; Sage & Armstrong, 1999). The system is decomposed into different components. The components will be treated as a “black box” with a clear boundary between the device and the environment around it (Dym et al., 2004). The boundaries of the components are drawn on the parts of the system that can have different owners. The components will have their own function.

The second aspect is the ownership aspects that are used in the breakdown of the system. Ownership comes forward to be very useful in the breakdown of the system. To find out if the system is broken down on the correct level, the question is if the component can have parts that can be owned by different owners. If the answer is yes, the system should be broken down further. If the whole system consists of components that cannot be partially owned by multiple owners, the correct level of depth is reached.

### Conceptual design

In the decomposition technique the system is broken down into different components. For this the question is asked: Can the components be split up in multiple components with clear functions? If the answer is yes, we should look at whether this split up is necessary for the correct level of aggregation. Creating components that are too small will unnecessarily decrease the speed of the method. Creating components that are too big will result in an incomplete analysis.

This means there are several demands for each of the

components. The first demand is that the functions of the components are clear. The second demand is that the component is connected to the components it interacts with. The last demand is that the component is broken down to a level which is compatible with the ownership configuration. For each component, the question is: Can this component be owned by multiple owners? If the answer is no, the correct level of aggregation is there.

In figure 7 is shown on how the system should look after the system breakdown technique. The boundaries, components and inputs and outputs should be clear. Also the connection between the components must be clear. The technical system will form the base for the next technique, the creation of the ownership configurations.

The goal of ROA is to address the differences in ownership risks. For this, the technical system is locked down. The technical system is identified and does not change in the further techniques of ROA. This makes it possible for the ownership configurations to be compared with each other. The ownership configurations will be based on the technical system.

### Case study

The system decomposition is based on the system description in the report “Converting excess wind power into power valuable products” (Stikkelman, 2014). Figure 8 provides a base system description for the system of a dual fired steam system. It is clear that there are some components identified. The three most logic components are the electrical boiler, the gas boiler and the steam client. The steam client uses the steam and the used steam/condensate is run through a condenser.

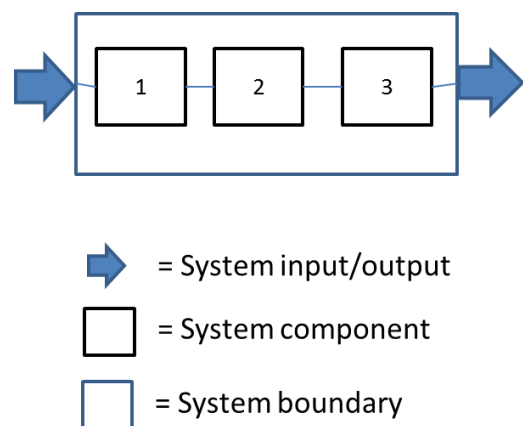


Figure 8: Visualisation phase 1 technique 2

This leads to the system having four main components that have to be coupled to each other. These four components are: A natural gas boiler, an electrical boiler, clients for the steam and a condenser to reduce the steam to water. These components are components that are generally owned by one owner and not split up. So the level of depth is sufficient. Another design factor is taken into account, the transportation and distribution. The distribution is a more important aspect when multiple steam flows are combined with each other. Therefore the pipelines and the combination of the two steam flows are taken into the system.

The amount of steam clients is not identified. This means that there is the possibility of multiple steam clients. This is taken into account in the configuration.

The main components are identified but still need to be connected to each other. This is done through pipelines. This leads to the last component, the combining and aligning of the two steam flows. This is a component that is not directly a large component, but could be owned by another owner. All the aspects are combined in figure 14.

As validation of the system decomposition, the technical system has been shown to employees of Stedin. From this no changes were added to the system. This makes the system the base for the further analyses. This moment is also the moment that the technical system is not expected to change anymore. A change in the system would lead to a new ROA.

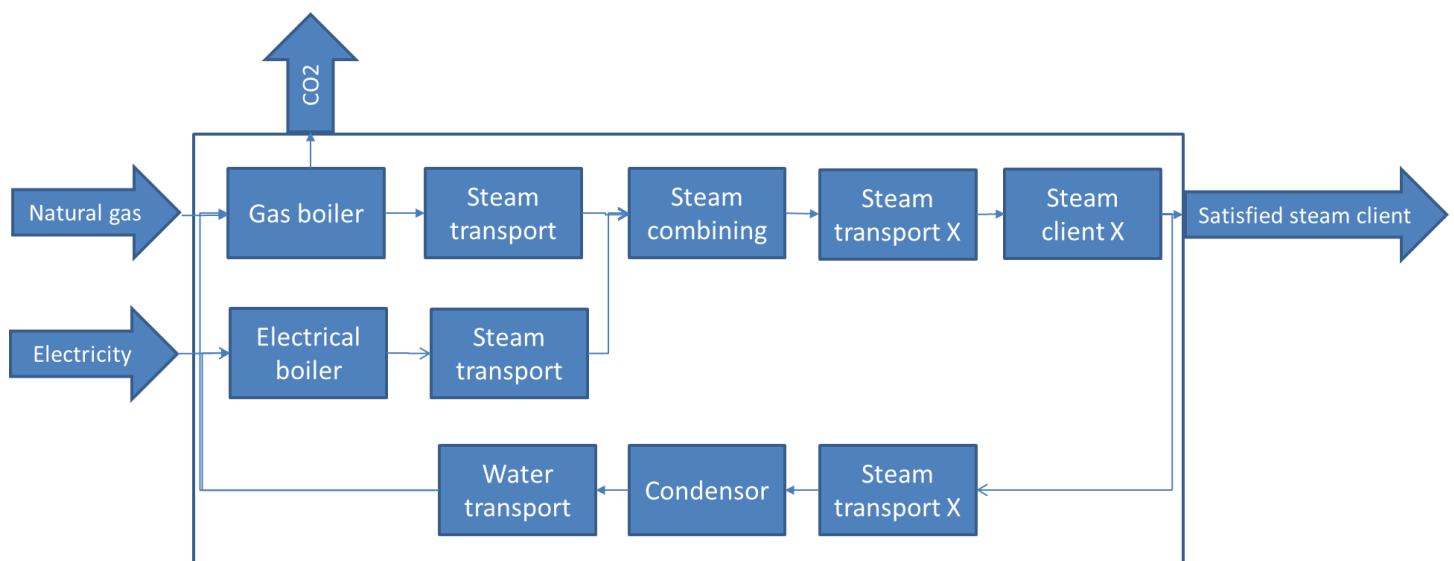


Figure 9: Output phase 1, technique 2 of the case study

### *Findings technique 2*

During the execution of the decomposition technique, two main findings were observed. The first finding is that the system consists of many different components. It is the question if all the components are of relevant importance. A steam pipeline expects to have fewer problems than a gas boiler. The finding shows that the method is aware that not all components have the same importance. The effect of this would come forward in the risk analysis further in ROA.

The second finding is that the clients of the steam system are not fully locked in. The steam system is expected to have multiple clients, but is not limited to multiple clients. This means that one of the goals of this technique is not met. The choice here has been made to analyse further with both options (multiple/single clients). This means that the component definition is not fully executed, but in the end should be evaluated on how it worked out.

The system still follows the main line from the report. For Stedin, changes have been made for the system. The combining of the steam and the pipelines are considered relevant for the possible owners of the different components of the system. It is the question is so much attention would be given to the pipelines if ROA was executed for another party.

### 3.2.3 Technique 3: Creating ownership configuration.

The system decomposition technique has provided a decomposed system. The next task is to combine the technical system with an ownership setting. The goal of ownership creation technique is to combine the institutional aspects of the system to the technical system. This is done through the synthesis of different ownership configurations.

#### *Theory*

The creation of the ownership configurations is done through a self-developed technique. The technique, relies on the expertise of the executors of ROA. The development of the configurations is done in two parts. The first part looks at the technical system and the ideas for ownership configurations. The second part selects ideas and translates them into ownership configurations. The amount of ideas is dependent on the time and resources available.

The first part focuses on the creation of ideas for ownership configurations. To create these ideas, a brainstorm session is performed on the technical system from the previous technique. It is expected that the executors have sufficient knowledge to analyse the possible ownership configurations. The focus of the first part is to think of as many possible configurations as possible. This can be done with few constraints. The only demand is that the ownership focuses on the components in the technical system.

The second technique is the creation of the ownership configurations. Owners are coupled to the different components. Each component can only have one owner. This leads to an extra ownership layer over the technical system. These ownership configurations should be created by people with the ideas from the first part in mind.

The ownership configurations are created by combining the ideas from the first part with the technical system from the previous technique. Each component will receive an owner. This is an extra layer on top of the technical system. In figure 8 this is shown.

What should be noted in this technique is that the ownership configurations are created by the executor of ROA. This means that this person/group also decides what should be compared. This gives the executor a lot of freedom and power.

#### *Conceptual design*

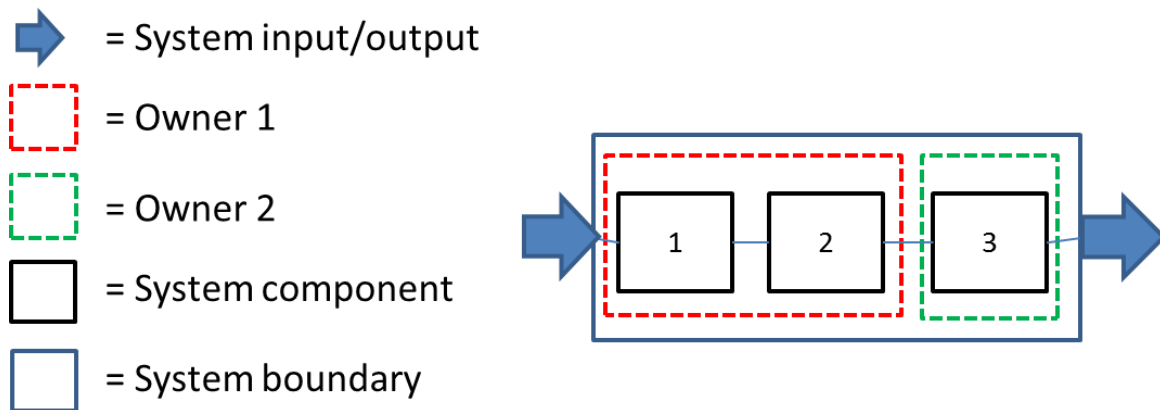
The ownership creation technique focuses on the creation of different ownership configurations to be compared in the next phase. The configurations are created through a brainstorm session. The technical system from the previous technique is used. The ownership configurations are based on the possibilities of the technical system. This possibility comes forward in the brainstorm session. All the ideas are written down and the most relevant ideas are worked out into configurations. The amount of configurations worked out depends on the preference of the executor of ROA.

The configurations itself will be plotted on the technical system where the components will have an owner. As shown in the example in figure 8, the technical system itself does not change. An extra layer is added to the system. This ownership is shown by the different coloured block around the components. To make the ownership configuration clearer, a description is added of the intended system.

The goal of the technique is to create multiple configurations. This is done by first brainstorming on possible ideas with the technical system. From the list of ideas the most viable ideas are worked out into ownership configurations. With the ownership configurations, the technical system gets an extra ownership layer. After the ownership configurations are created, the designing of the system is

done and the next phase of ROA starts. The next phase values the configurations through a risk assessment.

An important aspect is that the individual properties of owners will not be taken into account. A configuration can have different owners of components. But the financial power, preferences and other means of owners itself will not be taken into account. So it can be taken into account that a certain component has investment costs (component related), but not that an owner does not have



**Figure 10: Visualisation phase 1 technique 3**  
the financial means to pay for the component.

### Case study

The previously identified system is used for the creation of different ownership configurations. The goal of this technique is to create ownership configurations by putting an ownership layer over the previously identified technical system.

The ownership configurations are created by brainstorming about several possibilities on how this system could be designed with owners. From these thoughts, the most interesting thought are developed into configurations. The brainstorming has led to the following thoughts:

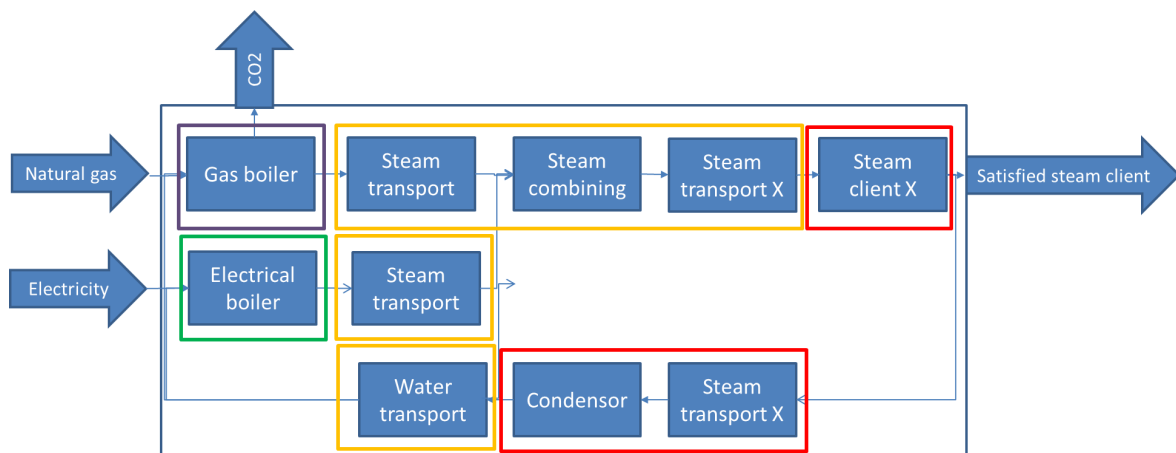
- One party that owns the whole chain. Only the clients will be another owner. However, the network owner could also be a large client of the system. The main aspect is that one party owns the whole production and sells steam as a package to the clients. The clients d profit less from the fluctuations and cheaper steam.
- Another option is that the whole chain is owned by different owners of the different components. This means the two boilers, the clients and the distribution system are all different parties.
- Another option is that the gas boiler and electrical boiler are owned and operated by the same party, but that the rest of the network is owned by another party. This party will have the responsibility of managing and distribution of the steam.
- Another idea is based on the current electricity system. The clients, and suppliers are all different parties. One party is the middleman. This party owns and operates the network. The system operator is responsible for the transportation of the steam and condensate. It also operates the supply and demand of the steam.

- Another option is that the gas boiler and electrical boiler are owned by different parties, but that the rest of the network is owned and operated by another party.
- The fifth option is that there is already a steam system based on natural gas. This system is owned by 1 party. Another party enters the system with a electrical boiler and will supply cheaper steam whenever the electricity based steam is cheaper than the natural gas based steam

Although five ideas were reasonable. Only two were further worked out because of time and resource constraints. With the employees of Stedin is discussed on what ownership configurations seem to be the most relevant to assess. The following ownership configurations have come forward:

#### Configuration 1

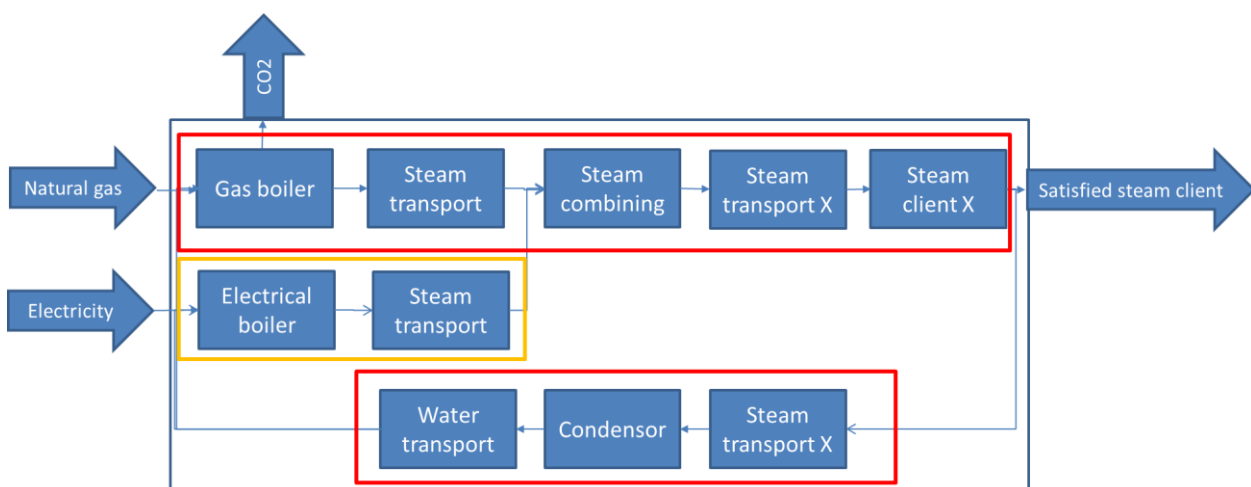
The first configuration is based on the current electricity system. The clients, and suppliers are all different parties. One party is the middleman. This party owns and operates the network. The system operator is responsible for the transportation of the steam and condensate. It also operates the supply and demand of the steam.



**Figure 11: Configuration 1: separated producers and clients. An independent distributor.**

#### Configuration 2

The second configuration is that there is already a steam system based on natural gas. This system is owned by 1 party. Another party enters the system with a electrical boiler and will supply cheaper steam whenever the electricity based steam is cheaper than the natural gas based steam.



**Figure 12: Configuration 2: Whole system owned by 1 party. Only the electrical boiler and transport to the system are from another party.**

### *Findings technique 3*

During the creation of the ownership configurations came forward that many people do not really have an idea on which configurations are viable. With different ideas, most of the ideas were accepted and not many questions were asked. It was the task of the executor to decide what ownership settings should be translated into configurations. The creation itself did not provide many problems.

The configurations that were chosen were based on personal choice in cooperation with Stedin employees. For Stedin the chosen configurations were favourable. In the workshop in the next phase, three configurations were originally presented. Because of time constraints, only two configurations were finally analysed. This resulted in two configurations that were presented in this section. With a broader case study, stranger configurations could be analysed. ROA could be tested on how these strange configurations would perform in ROA. This is something that should be noted for further testing of ROA.

In the first previous version of ROA, components were split up with an asset owner and an asset manager. In the workshop came forward that this had little added value for the identification of the risks. Thus the choice was made not to differentiate between asset owners and asset managers. In appendix 4 is shown that the workshop made use of the asset owner and asset manager structure.

## 4. Developing Phase 2: Valuing

The previous chapter shows that the first phase focuses on designing the different ownership configurations. This chapter gives values to the ownership configurations. This chapter consists of two parts. The outline is discussed in the first part. How should the phase be organized? Is the design possible with one technique, or are different techniques necessary.

### 4.1 Structure phase 2

The second phase focuses on the valuing of the configurations. These ownership configurations were created in the first phase. Phase 2 gives value to the configurations. This way they can be compared in the third phase.

In ROA, the configurations are valued with the use of risks. In other frameworks (Gómez et al., 2014) risks are used. It is expected that a configuration will perform better if it has less risks to deal with.

Since the configurations are measured by a risk assessment, the first step of phase two is the **identification** of the risks. The second step is the **assessment** of the risks. This will give value to each of the configurations. The output of this phase will be risk assessed configurations that can be compared to each other. Also the case study will be further executed

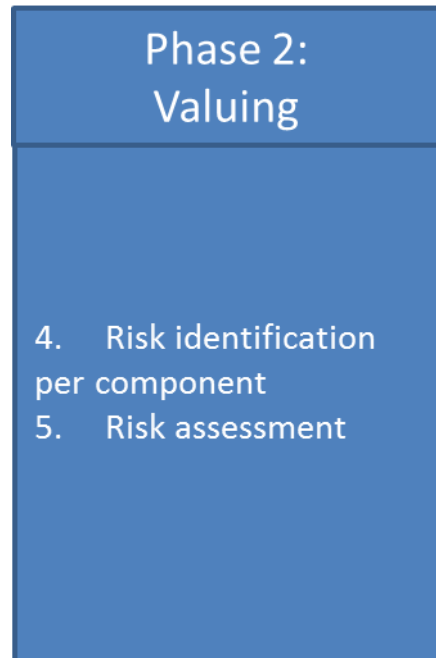


Figure 13: Summary phase 2

### 4.2 Techniques phase 2:

This chapter consists of two techniques. The techniques are explained in the following way:

1. First is the theory and reasoning behind the technique explained. How the technique should be handled.
2. Next is the conceptual design of the technique discussed. How is the technique executed
3. The third section discusses the case study. The technique is applied to the case study to test the technique as well as work on the case study
4. The last point is that the findings of the applied technique to the case study are discussed. What were problems that occurred when executing the technique?

#### 4.2.1 Technique 4: Risk identification

The goal of this technique is to identify the most relevant risks for the different components. The previous technique delivered multiple ownership configurations.

The risks will be assessed on a component level. This means that per component will be looked on what risks are relevant. The ownership of the component will be taken into account. The risks are identified with the question: what would be the risks of this component if it was owned by this owner?

The speed of the risk identification is also an important aspect. There is a possibility that this step is very time consuming. Since both per configuration and per component risks are identified. The amount of possible risks is very large. This is why the risk identification will be structured and concise. The goal is to identify the most important risks, not all the risks.

Important in the literature aspect is the method on how the risks are identified. There are many different ways on identifying the risks, but there is not much experience on how to identify the risks of a component with an owner.

### *Theory*

The risk identification is a step that is widely applied in research and projects. The risk identification is the first step and provides the basis for the next steps: analysis and control of risk management. The goal of the risk identification is well summarized in the following citation:

“Risk identification is a process that reveals and determines the possible organizational risks as well as conditions, arising risks. By risk identification the organization is able to study activities and places where its resources are exposed to risks.” (Tchankova, 2002)

The citation also presents the main problem in risk identification. The goal of a risk identification is to assess **all** the risks. If all the risks are identified, all possible problems are also identified. This means that all problems can be mitigated. However, it is not possible to identify all the risks. This means that another method needs to be used. Usually, a risk identification step is structured by identifying the risks through risk categories (Brændeland, Refsdal, & Stølen, 2010; Correa-Henao et al., 2013; Tchankova, 2002). The amount of categories and the amount of risks identified per category depends on the depth of the analysis.

Here comes forward that there is a big trade-off in the usability of ROA and the quality of the risk identification. Certain techniques allow for full risk breakdown structures and extensive risk calculations (Hillson & Simon, 2012). Whereas other techniques like the SWOT technique are too concise (Hill & Westbrook, 1997). The goal is to find a technique that has an acceptable amount of depth, where also the speed of the technique is taken into account.

The TECOP method is a method that is used for structure. TECOP is a Risk identification technique that allows to identify a large spectrum of the risks that are linked to a project or system. From the TECOP approach and an existing TECOP analysis (Glazer, 2013) can the different aspects be described as follows. The project identifies the risks according to the different aspects: These aspects are Technical, Economical, Commercial, Operational and Political. A large spectrum of risks is taken into account with the identification under these aspects.

The literature shows that it is difficult to identify all the risks because the risks are identified through a brainstorm session. To structure the brainstorm the TECOP method should be applied for each of the components. The TECOP method provides a base on which the risks can be identified.

### *Conceptual design*

The technique used for the risk identification is a structured identification session. This can be done by an individual or by a group, depending on the importance, urgency and necessity of the system analysed. The session is structured by systematically identifying the risks of each of the components of each of the configurations. So for each of the configuration each of the components is assessed. With each component, the question is asked: what would be the risks of this component if it was owned by this owner?

The TECOP method is a method that can be used to assess the different aspects of the risks that come forward with the different possible owners of components. This is a fast and structured way to assess the different risk aspects. Each component is looked upon and assessed through the different Technical, Economical, Commercial, Operational and political aspects. The risks that are identified

through these aspects are listed. After all the components are analysed, the ownership configurations are ready for the next step.

#### *Case study*

The risk identification has been done through a workshop at Stedin. The department of New Business Development was brought together. The different risks were identified as a group for the different ownership configurations. The department is involved in the whole process, from developing a steam system to operating the system. This means the New Business Development department consist of different specialists. This is expected to be sufficient knowledge for the case study.

The workshop started with an explanation of the framework and what was expected of the participants. The previous steps are explained to the participants that were not familiar with the method. It was clear on how the ownership configurations were made and what the goal is of the method. The participants knew they had to identify themselves with the components owned by an owner.

After the method was explained, the risks of the ownership configurations were identified with the use of the TECOP method. Per component was looked at the five categories of the TECOP method. When the risks were identified, the focus would go to the next component. This way all the components of two configurations were analysed and risks were identified.

The identification of the risks took longer than expected. This lead to that only two ownership configurations had their risks identified. It is decided to not take the third configuration into account with the further analyses. The results of the risk identification has been merged with the risk assessment in Figure 13 and figure 14 in appendix 7.

#### *Findings technique 4*

The fourth technique found out that it is quite hard to identify risks for each of the components. The Workshop went slower than expected. This led to only two configurations that had their risks identified. A third configuration was developed, but there was no time to identify the risk for this configuration. This is something to keep in mind for future ROAs.

It was also harder to keep the attention up for all the time. Perhaps the risk identification should have some diversity in it, so that the workshop is more fun/ energetic. This does not change the goal of the technique, but more the way it is brought in the workshop.

One of the main aspects of this technique is that the technique is heavily influenced by experts. This also leads to possible complications that can occur when using experts. For Stedin, the workshop was executed internal. But if the workshop was executed with multiple parties with different interests, strategic behaviour can occur. `

The risk identification is the collection of information from different sources. With larger projects, company privacy can become an issue in the risk identification. If incomplete information is available, opportunistic behaviour could occur. These problems should be mentioned and are a weakness for the method. The goal is to have complete and unbiased data. The problem is not a problem that can be solved, since it can occur in a competitive environment.

#### 4.2.2 Technique 5: Risk assessment

In this step are the identified risks valued. This step focusses on what the effects of each risk are estimated. With the values on these risks, the configurations can be compared to each other.

##### Theory

The risks are assessed with the ATOM methodology (Hillson & Simon, 2012). The ATOM methodology covers a broad range of full risk assessments with underlying thoughts. For this research is the method of assessing risks used. The ATOM methodology uses the product of the probability and the impact for the total effect of a risk.

The goal of this method is to identify the most important risks for the components. The ATOM method uses the product of two created values. This means that the score of a risk can increase quadratic if both values are high. This is also the intention, since the most significant risks will score much higher and less significant risks. The next step can discriminate between the more significant risks and the less significant risk. Appendix 3 elaborates on this.

##### Conceptual design

This step focuses on the valuing of the risk. The risks assessment is done according to the ATOM method. The ATOM method uses the probability of a risk occurring times the impact the risk would have when it occurs. The product of this will give a risk score. This is also explained in the formula below:

Risk score = probability \* impact.

The goal of this step is establish all the risks score by estimating the likelihood and the impact. As done in the previous step, a session is used where all the risks are valued. This can be done individually or in a group. The session defines the impact and the probability for each risk. These two values lead to a risk score. With the risk scores, the configurations are ready to be compared to each other in the next phase. Figure 10 shows a summary of this phase.

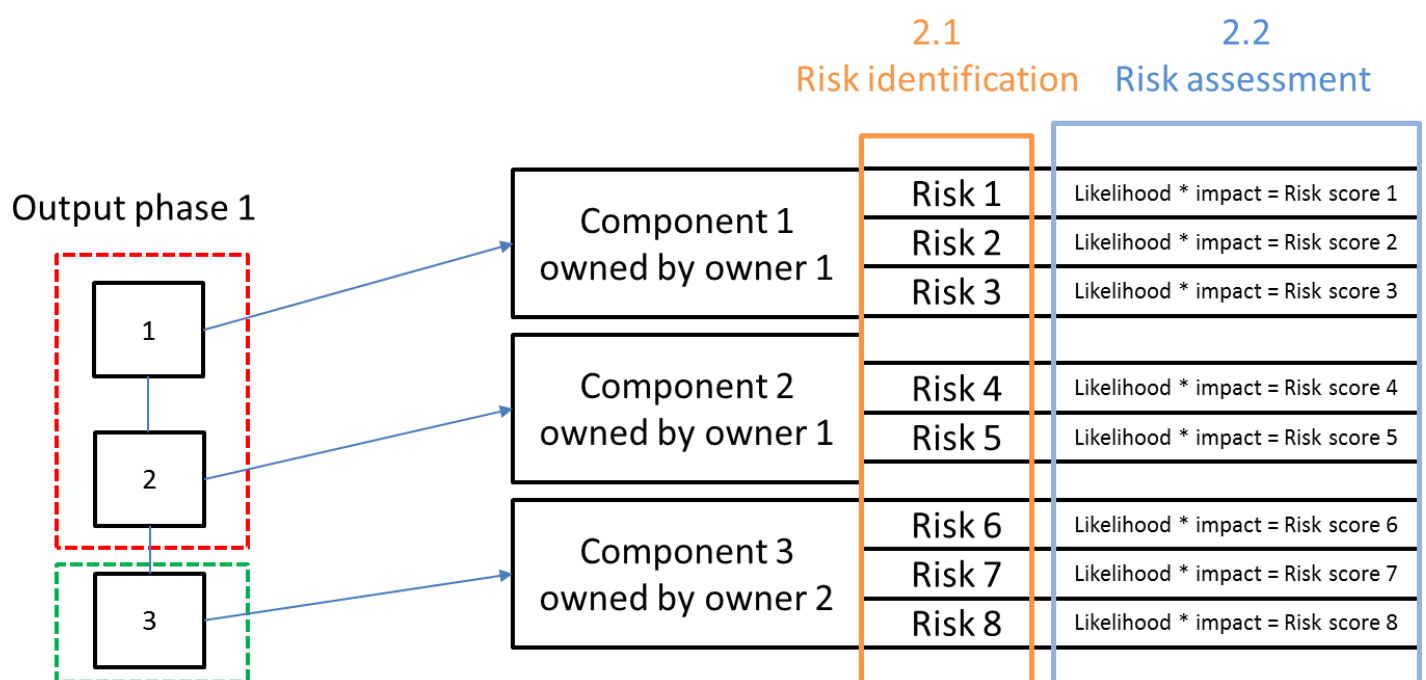


Figure 14: Visualisation phase 2

### *Case study*

This step gives values to the risk identified in the previous step. This have been done with the use of an expert's opinion. The values of the risks are split up in two aspects. The first aspect is the chance that the risk will occur. The second aspect is the impact the risk will have whenever it occurs. Both scores are ranked from 1 to 5, where 1 is perceived a very low chance or impact and 5 is perceived very high or likely.

For the risk assessment, the values have been generated with the help of an employee of Stedin. All the risks have gotten values and are also shown in figure 13 and figure 14 in appendix 7. These figures show the technical system with the ownership configuration. For each of the configurations are the risks identified. Each of the risk has several properties. The risk is coupled to a component with an owner, this means that the risk is owned by the component and thus the owner. The results of the risk analysis are used in the last phase.

### *Findings technique 5*

The original idea was to execute a componential risk assessment. The effects of the risks would be identified in five categories (TECOP). This way the effects of the risks could be categorized. The goal of the componential approach was to identify the specific sections where problems could be expected in the configurations. The choice was made with the risk assessment that the added value was too little for the work

The assessment of the risk showed some problems for the future steps. One of the problems was that at Stedin, relatively more risks were identified for the pipelines. This was expected, since the specialty of Stedin is pipelines. This is why the decision for the next step is made that the risks should be reduced to the most important risks. The asymmetry in knowledge on the different component should be captured this way.

The technique was executed with only two people. This leads to the possibility that certain risks would have less correct indications of likelihood or impact. The trade-off was made with that a larger group was harder to arrange and the risk valuing would also be executed more slowly.

## 5. Developing Phase 3: Comparing

This chapter discusses the third and last phase. The comparing of the configurations with each other. The structure is the same as in the previous chapters. First the general outline of the phase is discussed. The techniques are elaborated in the following sections.

### 5.1 Structure phase 3

The assessed configurations from the previous phase are used for the conclusions of the study. Phase 3 focuses on the extraction of useful information from the ownership configurations. The data generated needs to be interpreted and translated into relevant points to focus on. Since much information is generated in the previous phase, this phase focusses more on how to extract the information. A technique is developed on how to interpret the configurations.

This last phase has two techniques. The first technique uses the assessed configurations and uses the scores of the risks analysis to identify the strong and weak points of the configurations. The second technique will compare the different configurations and different criteria, and will provide the base for a solid decision support.

This chapter has the same structure as the previous chapters. First is the logic and theory behind the technique discussed. The conceptual technique is developed secondly. After the technique is developed, the case study is done with the technique. In the last step, the finding of the case study are discussed.

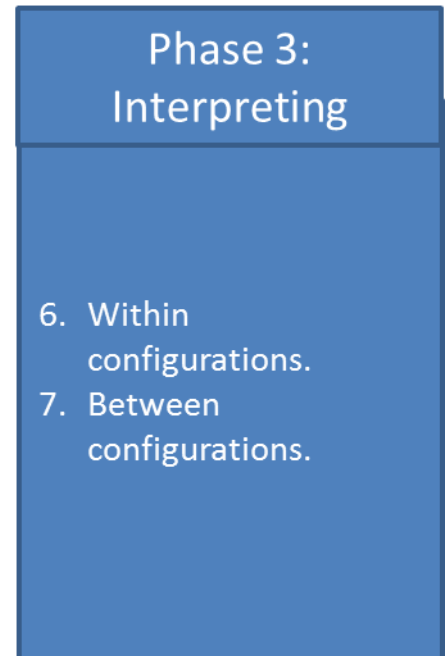


Figure 15: Summary phase 3

### 5.2 Techniques phase 3

This chapter consists of three techniques. The techniques are explained in the following way:

1. First is the theory and reasoning behind the technique explained. How the technique should be handled.
2. Next is the conceptual design of the technique discussed. How is the technique executed
3. The third section discusses the case study. The technique is applied to the case study to test the technique as well as work on the case study
4. The last point is that the findings of the applied technique to the case study are discussed. What were problems that occurred when executing the technique?

#### 5.2.1 Technique 6: Interpreting scores from each configuration

The first interpretation technique looks at the single configurations. These are risks coupled to a component and risks coupled to specific owners. Also the risks itself can be taken into further analyses. The goal of this technique is to interpret the correct information from the ownership configurations, so that the configurations can be compared in the last technique of ROA.

The comparison technique focusses on the parts of the system that should always be useful for ROA. Also a list is made with certain aspects that can be taken into account if the executor of ROA has specific demands.

### Theory

The literature on the interpretation on risks provides insight in what can be done with the risks and what cannot be done. The goal of this phase is to transform the data that is created in the previous techniques into useful data for the last technique. The interpretation of the data is something that will change per system that is analysed through ROA. However, there are always certain aspects that can be shown.

From the previous phase come ownership configurations with valued risks. It is expected that not all components will have the same amount of risks. This can lead to a distorted image of the different ownership configurations. Since the risks are identified in a workshop with people, it can be expected that the people will have more knowledge about specific components of the system. This could lead to more risks identified on this component. To capture this distorted view on the ownership configuration, only the highest scoring risks will be taken into account. It is important to take the most important risks into account. It is normal to value certain risks with a higher risk score more than other risks (Correa-Henao et al., 2013). ROA will take this one step further. The less important risks will not be taken into the next technique. Only the three highest risks or risks with a score of 13 or above are taken per component into the next technique. The score 13 is chosen so that only risks with a score of 2 4s or higher will be considered significant.

After the risks are reduced, the different aspects of the ownership configurations will come forward. This technique focuses on the basic properties that always should be viewed when analysing the ownership configurations. This means the total configuration score, the owner scores, the individual component and the biggest risks are treated in this analysis. Below each of these aspects is further elaborated upon.

- This section will discuss on how risks are coupled with revenues. The conclusions on the system components can be coupled to the revenues in the conclusion.

The total risk is the most straight forward approach on the different configurations. The scores of all the components are added to each other and give a total risk score of a configuration. This will give an impression on what ownership configuration will perform the best in general. However, this does not mean that this ownership configuration will be the most preferential.

The second aspect to compare the configuration on is the component with the highest risk. By listing the components on risk score, it can be compared what component brings forward the highest risk in a certain configurations.

The third aspect is the difference between the risks of the different owners of the configurations. The owners will own certain components of the system. These components will have risks scores. By adding the risks scores of the components, the owner will have a risk score as well.

The risk scores of the owners can be compared to each. It is not only the total risk scores that are interesting, but also the difference between the risk scores of the different owners. Since this model is to improve negotiations between parties, it is interesting to see which owners will carry the biggest risks in certain settings. Also the difference between the risks can also provide a lot of information. So if one party carries twice as much risks than another party. It can be expected that that this party should also be able to carry this risk.

The last aspect is to look at the highest scoring risks. This can show at the comparison if the biggest risks are the same with the different ownership configurations. This will show if there are big changes expected in the different ownership configurations.

#### *Conceptual design*

The first thing done in comparison within configuration technique is the reduction of the risks. It is expected that not all the components will have the same amount of identified risks. This is why the amount of risks are reduced to a maximum of three per component. The three highest scoring risks are used. This is done to eliminate the possibility that a component where a lot of small risks are identified will score disproportionately.

The risks itself are very useful and will create the risk scores for each of the components. The risk score is the sum of the three biggest risks that are linked to a component. The risk scores will be used in the next clarification of the technique.

The risks are used to make several lists in each of the configurations. This will help the next phase on comparing the different configurations with each other. Since not all systems have the demand for the same information, ROA can be adapted to specific demands of the executor. ROA will have a standard set of lists that can be used for the interpretations of the configurations. This list is described in table 1:

**Table 1: Description different criteria for measurement.**

|                                       |                                                                                                                                                                                                                               |
|---------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Highest risk score                    | The risk with the highest score will probably have a large impact on the system. The score itself can also be compared the highest risk form other configurations.                                                            |
| List component risks                  | Here the components are listed from the highest risk to the lowest risk. From here can be looked at the most influential components. These will carry the biggest risks.                                                      |
| List owner risks                      | The total risk of the owners can be compared to each other. The list shows what owners carry the biggest risks.                                                                                                               |
| List average owner risk per component | Since different owners will have different amounts of components. The average risk per component can also be taken into account. This will bring forward if certain owners will have components with a large risk on average. |
| Total risk score                      | The sum of all the risks of a configurations. This gives indication of the total risk score.                                                                                                                                  |

#### *Case study*

The configurations are analysed on different aspects. Fully risk assessed configurations were the output from the previous phase. This technique focusses on retrieving the information assessed in the previous technique. The output of this technique is shown in table 15 and table 16 in appendix 7. The results of this technique come forward in the next and last technique of ROA.

The case study showed that some components had significantly more risk identified than other components. His lead to the step that not all the risks should be taken into account when comparing the configurations. The idea was to reduce the risk scores to three per component. However, this way it would be possible that not all important risks were taken into account. This lead to an extra

step that the three most important risks are taken into the analysis OR all risks that score above a risk score of 13.

Another interpretation of the results is that the scores are calculated in an exponential way. This means that the effects of the risks can be harder to determine. Therefore, the risk scores are brought into a linear scale from 0-1. This is done by dividing the risk scores of the components by the highest possible risk score. The highest possible risk score per component is 25. This means the risk score is divided by the amount of risks of the risk score times 25.

#### Configuration 1

The first ownership configurations is the configuration with the distribution party and that different suppliers. The boilers are owned by different parties and deliver the steam to clients that own nothing else in the system. The steam is distributed by an external party. All results of the analysis are available in table 17 in appendix 7. Below gives a summary of

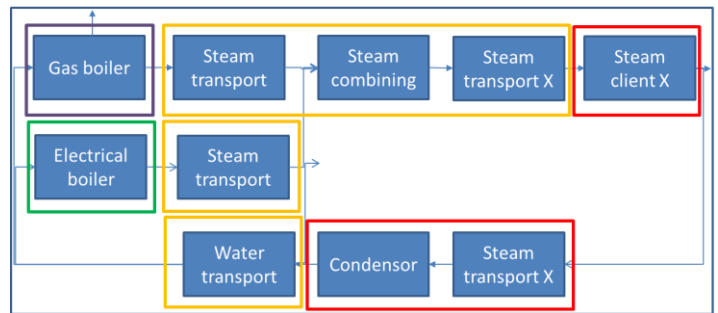


Figure 16: Configuration 1

the results.

#### Owner risks

The analysis shows that the biggest risks are carried by the distributor and the owner of the gas boiler. The electrical boiler owner also carries a risk, although not as big as the distributor and gas boiler. The steam clients carry a relatively low risk.

#### Component risk

The components with the biggest risks are the both boilers. Where the gas boiler carries the biggest risk. This is mostly because of the CO<sub>2</sub> price that is expected to rise in the future. The steam combining component and the steam clients also carry risks, although not that big. The pipeline behind the clients carries a bigger risk, since the condensate output from the clients could be of bad quality and lead to rapid aging of the system. The rest of the components carry very small/insignificant risks.

#### Individual risk

The highest risks are for both boilers that they get outcompeted by the other boiler. This is logical, since they are direct competitors of each other in the system. The third risk is that the CO<sub>2</sub> price will become high, which is a significant risk for the gas boiler. For the E-boiler it is the chance that they will have to pay a large capacity fee if the boiler is not operational.

From the data can be concluded that the comparable risks are carried by the owner of the boiler and the distributor, followed by lower risks carried by electrical boiler owner. The clients have the lowest risks. The gas boiler mainly carries a bigger risk because of the uncertain CO<sub>2</sub> price

### Configuration 2

The second configuration is the configuration where the natural gas system is owned by one party. A second party enters the system with an electrical boiler and delivers steam whenever the steam is cheaper than the natural gas steam. All results of the analysis are available in table 18 in appendix 7. Below gives a summary of the results.

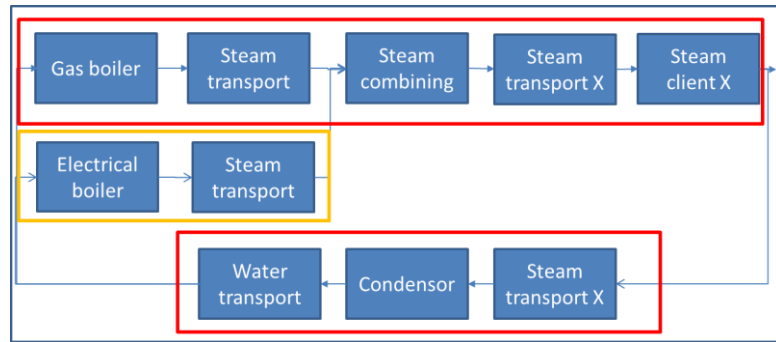


Figure 17: Configuration 2

### Owner risks

The two owners of the system both carry relatively large risks. This is logical, since they operate the whole system together. The large owner carries a bigger total risk, but a relatively small risk per component. The smaller owner of the electrical boiler carries a smaller risk, but still big. The score per component of the second owner is quite big.

### Component risk

The components with the biggest risks are the both boilers. The electrical boiler carries the biggest risk. This is because it can be cut out by the big owner in the configuration. The gas boiler also carries a large risk. This is mostly because of the CO<sub>2</sub> price that is expected to rise in the future. The steam combining component and the steam clients also carry risks, although not that big. The pipeline behind the electrical boiler carries a bigger risk, since the investment could be useless if the electrical boiler is locked out. The pipeline behind the clients carries a bigger risk, since the condensate output from the clients could be of bad quality and lead to rapid aging of the system. The rest of the components carry very small/insignificant risks.

### Individual risks.

The biggest risk of this configuration is that the smaller owner gets dominated by the big owner. This risk scores higher than all other risks, the other big risks are the both boilers get outcompeted by each other. The CO<sub>2</sub> price also plays a bigger role in the risks.

From this configuration can be concluded that the owner of the gas system carries a relatively low risk and the electrical boiler carries a big risk. This could lead to the risk that the big system owner is not dependent on the electrical boiler, but the electrical boiler is dependent on the big system owner. Effects like the CO<sub>2</sub> price reduce this effect a bit, but the difference between dependence is a major factor in this configuration.

### *Findings technique 6*

The comparison within configurations technique provided one main finding. The owner risk score per component gives a distorted image. Since the components are not equal in value or revenue. The result of the distorted image is that low scores are inconclusive. Only high scores can give extra information. This can be further evaluated in the evaluation.

The first configuration has an owner that owns and operates the pipelines, this is a role that Stedin could fulfill. The second configuration is much harder for Stedin to fulfil. Therefore the interest with Stedin lies in finding advantages on the first configuration compared to the second one. In the second configuration comes forward that there is a large drawback. This is how the method could be used in a strategic form, the selective information can be used for favour certain configurations instead of other configurations. It is not the goal of the scientific method, but it is an application for Stedin.

### *5.3.2 Technique 7: Comparing the configurations*

The last technique consists of a comparison of the different configurations. A huge amount of information has been generated and it is the task of this technique to make this information easily interpretable for the people. The goal of this technique is not to aggregate the results generated in the previous technique. The goal is to visualise these results and give a clear overview of the different configurations.

In the previous technique, the configurations already have been analysed individually. In this technique, the configurations are put together and the information should be clear for interested readers. The table should consist not only the scores, but also the configuration explanations itself.

### *Theory*

The previous technique focused on the extraction of the data. The goal of this technique is to compare the data of the different configurations. The configurations are compared on the different aspects and qualitative conclusions are drawn.

Since the configurations are created the same way and assessed on the same level. The configurations can be compared directly to each other. There are no extra techniques necessary. The ownership configurations are compared on the different aspects like biggest risk, total risk score, owner risk score and component risk score. The conclusions from the different aspects can be summarized in a total conclusion.

One of the main aspects is how to value the different scores. What is a significant difference in the risks between the two components?

### *Conceptual design*

The results of the previous technique have aligned the different configurations. The task of this technique is to join the configurations in a table. The information will be presented next to each other and the different aspects are analysed. From the information conclusions are drawn on the biggest differences between the ownership configurations.

The different categories from technique 6 are used for the comparison of the configurations. Each of the categories is put into a table with the relevant data from each of the configurations. All the configurations are also put in each of the table with their relevant scores. This gives four tables. Total risk score, the different component scores, the owner scores and the five biggest risks of the configuration.

The total score compare directly to each other. The total performance of the configurations are estimated through the most important risks. The total scores give a good impression for the total performance of the system.

The components can also directly be compared to each other. The difference in risk scores can be identified quickly. Qualitative conclusions can be drawn from this information. Also the differences in specific components provide an interesting view.

The owner scores are a difficult aspect to compare, since not all owners have the same amount of components. Therefore the owner score is split up in two scores. The total risk score per owner and the average risk score per owner. From this aspect different conclusion can be drawn. Some owners will carry a big risk overall. Whereas other owners can carry a big risk per component.

The biggest risks will look at two main points of the risks. The first point looks if the five biggest risks are the same in the configurations. It could be possible that certain risks are very big in certain configurations. The second point looks at the scores of the risks. Sub conclusions can be drawn from this.

The sub conclusions can lead to a total conclusion of the ROA. A conclusion can be drawn on what configuration will perform the best. Also certain considerations can be made in the choice of the optimal configurations. The goal is to provide a support for decisions that can be made.

#### *Case study*

The comparison between configurations technique compares the ownership configurations. The two ownership configurations are integrated into 1 table, which will provide information on how the different ownership configurations will perform. This is shown in table 7.

**Table 2: Comparison total risk scores of the configurations.**

|                  | Configuration 1 | Configuration 2 |
|------------------|-----------------|-----------------|
| Total risk score | 1,49            | 1,53            |

From the comparison between the two total configurations can be said that both configurations score quite similar. No real conclusion can be drawn from the difference in the total risk scores.

**Table 3: Comparison owner scores of the configurations**

|               | Configuration 1 |      | Configuration 2 |      |
|---------------|-----------------|------|-----------------|------|
| Score owner 1 | 0,43            | 0,43 | 0,87            | 0,11 |
| Score owner 2 | 0,45            | 0,09 | 0,67            | 0,33 |
| Score owner 3 | 0,25            | 0,08 |                 |      |
| Score owner 4 | 0,36            | 0,36 |                 |      |

The table above shows the comparison between the owners of the different configurations. Per configuration are the owners listed with two scores. The first score is the total risk score they carry. The second score is the risk score the owners carry per component.

From the comparison between the owners come interesting aspects forward. The first aspects is that the owners from the first configuration carry much smaller risks per owner. However, the risk they carry per component are much bigger. This is because owner 1 and 4 of configuration one own the both boilers.

The party form the second configuration that owns the large part of the system, carries a big risk. The risk per component is very small. The second party (owner of e-boiler) carries a smaller but still

big risk and only over a few components. The core per component is very high for this party. This part scores both high in the risk it carries and the risk per component.

From the ownership comparison can be concluded that in the first configuration the risk is much more divided. In the second configuration, a large risk is carried by few components. Owner 2 of configuration 2 is expected to have to deal with the biggest risks. The boiler owners (owner 1 and 4) of configuration 1 also carry relatively high risks.

**Table 4: Comparison component scores of the configurations**

|              |                                   | Configuration 1 | Configuration 2 |
|--------------|-----------------------------------|-----------------|-----------------|
| Component 1  | Gas boiler                        | 0,43            | 0,36            |
| Component 2  | Steam Pipeline                    | 0,04            | 0,04            |
| Component 3  | Steam combining piece of pipeline | 0,21            | 0,16            |
| Component 4  | Steam Pipeline                    | 0               | 0               |
| Component 5  | Steam clients                     | 0,25            | 0,15            |
| Component 6  | Electrical boiler                 | 0,36            | 0,43            |
| Component 7  | Steam Pipeline                    | 0,04            | 0,24            |
| Component 8  | Steam pipeline                    | 0,16            | 0,16            |
| Component 9  | Condensor                         | 0               | 0               |
| Component 10 | Condense pipeline                 | 0               | 0               |

From the comparison between the components comes forward that in both configurations both boilers carry the biggest risks. Also the clients of the steam system have some risks. What is interesting is that in the first configuration, the risk of the gas boiler is higher. In the second configuration more risk is carried by the electrical boiler. Another significant difference in the risks is with the pipeline behind the electrical boiler (component 7). The risk of this component is much higher in the second configuration. This is because the chance of an unprofitable investment, since the configuration could lead to an exclusion of the electrical boiler. The other pipelines and condenser carry small to neglectible risks.

**Table 5: Comparison biggest risks of the configurations.**

|         |                                                                                                                                   | Configuration 1 |                                                                                                                                                                 | Configuration 2 |
|---------|-----------------------------------------------------------------------------------------------------------------------------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Risk #1 | The risk that the gas boiler gets outcompeted by the electrical boiler through lower electricity prices and/or higher gas prices. | 0,6             | The electrical boiler subordinate to the big user of the system. The main user can decide to take off steam of you.                                             | 0,64            |
| Risk #2 | The risk that the electrical boiler gets outcompeted by the gas boiler through lower gas prices and/or higher electricity prices. | 0,4             | The electricity price becomes higher and the steam produced by electricity is more expensive than the steam producer by natural gas. There is a positive spark. | 0,4             |
| Risk #3 | CO <sub>2</sub> price is raised through policy measures                                                                           | 0,36            | The electricity price becomes lower and the steam produced by electricity is cheaper than the steam producer by natural gas. There is a negative spark          | 0,4             |
| Risk #4 | The middleman(owner 2) asks a                                                                                                     | 0,36            | CO <sub>2</sub> price is rising through policy                                                                                                                  | 0,36            |

|         |                                                                                                                          |      |                                                                                                                                                            |      |
|---------|--------------------------------------------------------------------------------------------------------------------------|------|------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
|         | too big margin for the steam delivered                                                                                   |      | measures.                                                                                                                                                  |      |
| Risk #5 | The e-boiler is not operational and a large capacity fee has to be paid for the electricity connection with the e boiler | 0,36 | Gas has less buying flexibility than electricity, this means that the gas boiler could have the problem that it cannot deliver steam whenever it is asked. | 0,32 |

The Biggest risks of both configurations have much in common. IN both configurations there are two risks that the boilers will compete each other out of the system. This is significant. The biggest risk is specific for the second configuration. This is that the owner of the largest part of the system (owner 1), will decide to not deal with the electrical boiler. The electrical boiler would then be left aside in the system. This risk is valued as the biggest risk. The third risk that comes forward in both systems is that the CO<sub>2</sub> price is expect the rise in the future.

### Findings technique 7

The finding of the last technique is that it was in the first version hard to compare the different configurations. The normalisation of the risk scores provided a more easy approach to compare the risk scores. What one of the more interesting findings was, was that the biggest risk in the second configuration was not at all available in the first configuration. Other risks had minor differences in score.

One of the main aspects is that in the first configuration, the distributing party carries a relatively large risk. This should be coupled to the fact the distributing party has an extra role instead of only operating the pipelines. The risks should come with more earnings. It is clear that both the gas boiler and the electrical boiler carry a high risk high reward system, but in the first configuration also comes forward that the distributor also carries a bigger risk.

The second configuration has a more direct approach, since most of the system relies on one party. The other party is dependent on the big party and this is also the weakness of the configuration. The risk carries by the smaller party is relatively big. It could be argued that a system owner by one party is therefore less likely to adapt to the new system. External drivers like competition and taxes could lead to changes in such a system.

For Stedin the interest lies mostly in the first configuration. The role of Stedin is associated with owner 2. With future discussions can be brought forward that Stedin can handle the role as operator of the system. If we look at the risks of the other owners in the first configuration, the risks are all much lower than in the second configuration. With possible negotiations, this could be brought forward in favour of the first configuration. T

### 5.3 Case study results

The case study for ROA was conducted on a steam system which uses both natural gas and electricity as resource. The case study analysed the role that Stedin could possibly fulfil in this system. In the two analysed configurations risk were identified for two ownership configuration settings. The first configuration was a configuration where one party had a role that Stedin could fulfil. The second configuration analysed the system where one main party owned a large portion of the system. It would be very hard for Stedin to fulfil a role in the second configuration.

The risks of both configurations do not differ much in total. The difference is in the risks that are carried per owner. In the second configuration, the biggest risks are carried by the biggest party, which can also make the most profit of the system. In the second configuration a relatively high risk is linked to the smaller owner, due to the fact that this small owner could be excluded from the system by the large party in the system.

For Stedin the interest lies mostly in the first configuration. The role of Stedin is associated with owner of the pipelines in the first configuration. Stedin can handle the role as operator of the system. If we look at the risks of the other owners in the first configuration, the risks are much lower than in the second configuration. In negotiations, the first configuration will be favourable.

ROA could be used for Stedin in the future. The information gained from the analysis can be used in the negotiation sessions with other parties. If the ROA is executed internally, Stedin has an advantage in the negotiation sessions with the information and risks available. The alternative is that ROA could be executed with multiple negotiation parties, but more research is necessary for this.

## 6. Evaluation of ROA

This is the report on the creation of a Risk Ownership Assessment (ROA). ROA is a method which can be used to assess the effect of ownership structures in a technical system. The aim of ROA is to act as a tool to analyse the risks of different ownership possibilities in a system. The ROA created is ready and fulfils this purpose, but it is certainly not perfect. This chapter evaluates how ROA performs on different aspects. The method is evaluated and the strengths and weaknesses are addressed. The evaluation is divided in two different categories: functionality and usability.

### 6.1 ROA evaluation on functionality

The functionality evaluation focuses on the content of the method. Does the method do what it should do?

#### 6.1.1 Degrees of freedom

One of the main aspects in the method is that there are many techniques with degrees of freedom. The configurations and the risk identification have both a large margin that needs to be taken into account. Many decisions are made in these techniques which can and will influence the outcome. This trade-off leads to a faster model execution. The total amount of options is too many to analyse them all.

The many degrees of freedom lead to questions about the reproducibility of the results of the method. What differences would there be if ROA was executed at different times? Changes could be made in the choices of configuration that are analysed, risks could be valued differently and other risks could be identified. The power of the analysis lies not in the degrees on freedom of the method, but in the ability to produce arguments to choose for a certain ownership configuration. This does not mean that the analysis is useless, but that the results can be questioned.

The power of ROA lies in the same approach for comparing different configurations. Since the analyses are quite qualitative, the results of multiple ROAs should result in the same qualitative results. However, differences could occur in the value of certain risks. These differences in values could provide extra information as decision support.

#### 6.1.2 Ownership

ROA focuses on the integration of ownership settings with a technical system. Ownership is used as a factor in the breakdown. The case study shows that the breakdown is not optimal for the system. In the case study, several components received small to no risks. The question rises if the components should be used in the future development of ROA. The effects of identifying low-impact components are twofold. On the one side, the identification causes extra time spent on ROA that is not necessary. However, when the components were identified, it was not known that these components would score low on risks. The other option is to have another component identification process. Another rule could be developed to break the system down. This would require a new development of the system breakdown for the ROA method.

From a system point of view, the system could be identified differently. From a ROA point of view, it is good that all different possibilities are taken into the analysis. The time lost in the extra components was not significant. The possibility exists that when low-impact components are not taken into the analysis, the system will miss important information as decision support.

## 6.2 ROA evaluation on usability

Since the goal is that ROA will be used after this research, it should be a usable method. In this part of the evaluation is looked at what is necessary to use ROA in future projects. What are the demands of the project to be able to execute ROA? Three points are factors in usability: the ownership configurations, the speed of execution and the users of ROA

The main point that should be mentioned is that ROA is not a 360 degree analysis on a system. Only the ownership aspects are treated and mainly the risks that are linked to ownership are mentioned. ROA gives insight in how a system can be designed with multiple ownership configurations.

### 6.2.1 Ownership configurations

The main usability demand for ROA is that the system that is analysed is compatible with ROA. The system needs to be compatible on two aspects: the breakdown of the technical system and the creation of the ownership configurations.

For the breakdown of the technical system, the system needs to consist of components that can be owned by parties. The demand is that the technical system needs to be broken down so that multiple ownership configurations can be created, but the technical system still stays the same.

For the creation of ownership configurations the components need to be scoped in a way that multiple owners could be applied. If this is not the case, the effect of the ownership configurations is gone. It is crucial that multiple ownership configurations can be created.

### 6.2.2 Execution speed

The speed of the method is one aspect that needs to be addressed. Since the method creation and the case study were done almost simultaneously the speed of execution of the method has not been thoroughly addressed. The method needs to be executable in a reasonable amount of time (1 week). This is under the presumption that all the information necessary is available.

One of the main researches ROA is based on is the CODAN framework(Gómez et al., 2014). The difference with ROA is that the CODAN framework is a framework for simulation models. ROA is more aimed at a less extensive analysis and a more decision support tool. This is coupled with a faster execution time and a more transparent approach. The transparent approach and speed are both taken into account, but could be more optimized.

The case study that was executed took much longer than the estimated time. The method creation interacted with the case study. These processes happened simultaneously and adaptations were made on the method while working on the case study. This has led to the ownership layers, removal of the asset owner and asset manager aspect, the risk reduction, the adaption to the risk reduction and the risk interpretation calculation. All these changes led to a longer case study and thus no expectation on how long the method takes to execute, but it also improved the method.

Another aspect of speed is that the method made use of many different software tools. Many of the techniques were executed on paper, but were elaborated in different software tools (PowerPoint, excel, word). With dedicated software, the ROA execution time could be reduced significantly.

The ROA method aims to be executable in a reasonable amount of time. ROA should be executed within a week time. The case study is not a reliable benchmark for the execution time, since the case study also led to many improvements of the method. Another case study should be executed to see if ROA is executable in a reasonable amount of time. Dedicated software could also improve the execution time of ROA. Further research should be done to make this possible.

### 6.2.2 Users of ROA

The last evaluation point is aimed at the possible users of the method. The case study showed that certain knowledge was necessary to execute ROA. The executor of the ROA needs knowledge on the system that is analysed, the components and the risks that are linked to these components. This way, the only possible users for the method are experts on the system.

The knowledge required for ROA is significant. The phases require knowledge on systems, components and risks. Since only experts on the system can be expected to have this knowledge. The method can exclusively be executed by experts. Is there a possibility for less informed people to execute the method?

The method can be split up into different deliverables. Certain techniques could be done by other people and the outputs of the phases can be used by other people. For instance, the ownership configurations could be created at one place, where the risk identification and further techniques are done by a different group.

One of the main aspects of ROA is that the method is heavily influenced by experts. This also leads to possible complications that can occur when using experts. For Stedin, the workshop was executed internal. But if the workshop was executed with multiple parties with different interests, strategic behaviour can occur. Also aspects as opportunistic behaviour and contestable data are problems that can occur in a competitive environment.

The aimed users for ROA are experts that know how the system functions. The idea is that these experts come together and share their views on the system. This can be within a company, but also in a negotiation session. With the use of ROA, the goal is to reach consensus on a project decision. This the goal of reaching consensus by providing decision support. The method could be used for decision support in multi-actor projects, but the method itself should be tested on how it would perform in a competitive environment.

## 7 Conclusion and recommendation.

### Conclusion

The motivation for this research was to provide a possible solution to the ownership problems that Stedin encounters. Currently, this is a relevant topic because plans for setting up steam systems for cheap peak electricity are made. The goal is to be able to define the most optimal ownership configuration for this sociotechnical system.

Literature has shown that problems in technical systems can often be addressed with a three step-method. In this case, the method should assess the effects of ownership on the system. The method is created and is called the Risk Ownership Assessment.

The first phase of the method focusses on the set up and design of the technical system. The goal of this phase is to create ownership configurations. Techniques that are used are: 'defining the system', 'decomposing the system' and 'applying the ownership configurations'.

The second phase of the method focusses on valuing the different ownership configurations. The configurations are assessed through risks so that they can be compared in the last phase. Techniques that are used are: 'risk identification' and 'risk assessment'.

The third phase focusses on the interpretation of the configurations of the previous phase. This phase consists of two techniques: the interpretation of each individual ownership configuration and the comparison between the ownership configurations.

During the research, the ROA method was improved and validated with a case study at Stedin. The case study focused on a coupling of a gas boiler and an electrical boiler in a steam system in the Port of Rotterdam area. Two ownership configurations resulting from the method's first phase were compared. The first configuration focusses on a split up system, where the electrical boiler, gas boiler, pipeline system and the clients were all different parties. The second configuration focusses on a large dominating party, where a party with an electrical boiler wishes to join the system.

The case study showed that the method was able to assess effects of different ownership configurations and provide qualitative data on the matter. As it turned out, the natural gas boiler carries a bigger risk than the electrical boiler, since the CO<sub>2</sub> price is uncertain in the future. The distribution system carries a relatively large risk. It implicates that this should lead to more revenues for the distribution. A system with a large dominating party is not beneficial for the less dominating parties. However, the whole system does not carry much more risk than the other configuration.

The case study provided the first level of evaluation. In the case study, practical improvements were made. Many of the developed techniques were clear on paper, but showed some practical problems with the execution.

ROA was evaluated on four points: degrees of freedom, ownership, speed and users. From the evaluation comes forward that the method fulfils its demands, but at this time it can only be executed by experts. This can also cause issues in negotiations. Since ROA is executed by experts. ROA is vulnerable for both strategic behaviour as well as opportunistic behaviour. Also, the method will be more time consuming when the amount of configurations increases. These points should be taken into account when defining improvements for the usability of the method

### Recommendations:

The recommendations on this research focus on the possibilities of the method. With an improvement of the method, the trade-off between the comfort of the method and the depth needs to be kept in mind. Since simply asking for more depth in ROA will not do much good for the comfort/speed. There are some possibilities that have smaller trade-off effects and could be used for further research.

The first recommendation is that the Risk Ownership Assessment could be aimed to be executed by a bigger audience. At this time, the Risk Ownership Assessment can only be executed by experts that have knowledge and insight about the analysed system, and the risks that come with it. Further research could possibly adapt the Risk Ownership Assessment to be applicable to a broader audience.

The second recommendation is directly linked to the first one. Since expert are the only executors of the Risk Ownership Assessment at this time, the Risk Ownership Assessment could be used as a consultancy tool. The method could increase the effectiveness of consultants, since the method provides new insights and does not take that long to execute.

The penultimate recommendation is that the method is not yet executed optimally. A dedicated interface could increase the speed of the method drastically, without comprising in the depth of the method. The development of such software costs time and money. The development of an interface did not fall into the scope of this research.

One of the recommendations is to assess more different cases. From the analysis of different cases, behaviours could be identified. These behaviours could lead to certain standard archetypes. Data analysis on the results could provide these possible archetypes, which could lead to a set of rules for designing with ownership in mind.

## 8 Reflection

The chapter reflects on the research as a whole. The first aspect is the reflection of the research approach. The scientific relevance is reflected upon secondly. The practical reflection is the last aspect that is reflected upon.

### 8.1 Reflection on research approach

The research is conducted through a method. The research tried to integrate the institutional aspects with a technical system. The different aspects are usually treated next to each other. ROA integrated these two aspects into an analysis that is useful for possible parties interested to participate in multidisciplinary projects.

Another option to treat such problems is through expert interviews. The problems discussed could be solved by letting people with knowledge on the subject shed their light on the possibilities. However, the power of the method could be that other conclusion come forward than what the experts usually say. Also the structure could lead to better reproducible results as well as that people will conduct a more complete analysis on the subject. By systematically addressing all the components, there are less likely problems missed.

The research consisted of two combined processes. The first process is the problem solving of the case study. The second process is the development of a method. The process of the development happened simultaneously with the method. The method was developed, applied to the case study and then evaluated and changed if it required change. If the technique was changed, the new technique was applied to the case study.

One of the advantages of this way of conducting research is that the process has a build-in validation. The results of each step can be checked immediately by the case study. This also led to some adaptations in the method. This iterative approach also showed more insight on how the case study could be further developed.

One of the possible downsides of this way of conducting research is that the development of the method focuses too much on the case study and therefore gets too customized. The goal of the method is that it could possibly be generalised for other problems. This is handled in the evaluation of ROA, but the method chosen to conduct the research provides an extra risk. For the execution of the method, knowledge about the system is required. There are two aspects of the method that come forward here. The first aspects is that if the knowledge of the method is already available by the experts, is such a method still necessary. The experts could also come together and decide on an optimal setup. The result could be comparable, but the method could also lead to different results. This could lead to a possible comparison between the two ways of deciding on such projects. ‘

### 8.2 Reflection on scientific aspect

The scientific aspect of the thesis is the combination is the combining of ownership with the technical system. From the research came forward that this had not been done in the research that was analysed. Normally institutions are approached through a more soft aspect. This research tried to make institutions more “hard”. The institutions are structured and used in a still qualitative approach. It is the question if these ownership institutions will provide a full spectrum on the problem, or if ownership is not enough.

Transaction costs economy is also an aspect that could be taken into account with the method, since now only a new system is analysed. But this is something that could come forward in a technique after the method.

### 8.3 Reflection on practical aspect

The research has been executed mainly for two parties. The first party is Rob Stikkelman. ROA can work as an extension of his previous report on how to use cheap peak electricity. The second party is Guy Konings. ROA can support how business is executed at Stedin.

ROA could be used as an extension of the report: Converting excess wind power into power valuable products. The extension of the report was quite clear. The steam in the port of Rotterdam is a viable option. Let's see if we can do something with the ownership and system. This could lead to other risks that we can also take into account when creating such a steam system. The system is new and will probably have start-up problems. Every problem we can take out of it, is a problem less to deal with when the system is built. And will also increase the chance of the system being build.

For Stedin was the project less clear in the early stages. The thesis focus lied more to the use of steam in the port of Rotterdam, and only after a longer period of muddling through that project. The change was made after some time for creating a method which could be applicable on more projects.

Both of these aspects show that the ease of the method is crucial if the method is to be used in the future. This has led to two main aspects that are crucial to this aspect after the method has been build and tested. The first aspect is the speed of the method, the method needs to be executed fast to have enough comfort. The second aspect is that the knowledge necessary for the method could lead to a barrier to execute the method.

The goal of the research is that the method could easily be executed. The method could also be adapted for consultancy firm to execute an analysis of a possible project. The aim at which such a method could be executed is 2-3 days.

Software is something that could increase the usability of ROA. With dedicated software, ROA could probably be executed in 1 day. The goal of ROA could be more orienting on such project instead of the more explaining technique for what it is used at this time. This is something that could probably be done in another research. This is something that

#### 8.4 Reflection on personal aspect

Writing a thesis was one of the harder things I did in my life. At the TPM faculty, students write multiple reports in their student careers. However, a master thesis is something of another level. You are confronted with your own shortcomings. These shortcomings have come forward and are discussed below

The first aspect is that I don't like failure. This aspect has led to not taking further technique in my thesis and thus procrastinating the whole project. The situation I was in was fine and I kept telling myself that I did not need to rush, which led to me doing nothing at all. At one point I read the text: the best time to plant a tree was 20 years ago, the second best time is today. Which motivated me to really invest in the thesis and start up the process to finish this project.

The second aspect is that I like to move forward, even when not all the gaps are filled in. This has led to a method which was nice by itself, but I needed guidance in how to get to this method. This was a point in the thesis where I noticed that this is one of the points I will probably encounter more in my life.

The last thing I learned is that structure is everything. One big moment was the moment that someone said to me: your substance is fine, but your structure is terrible. This has led to me contemplating my whole way of thinking and how to change this. This is one of the lessons that was not only useful for my thesis, but also for the rest of my life.

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## Appendix 1: systems thinking

The second aspect in the research question is the system. The framework will compare different systems with each other. For this is looked on how a system is interpreted. The research question focusses on the different ownership models. Three different sources provide in their own way an interesting view on systems and systems thinking. The goal of this section is to show how system can be interpreted and what should be taken into account.

The first article is a manual of a steam system(Canteach, 1996). The manual explains how a system is broken down and what is should be the functions of the system. The methods used on modelling the system are useful for describing other systems. The system is first described with the general functions of the system, which are translated into two kinds of requirements for the system. The first are the process related requirements of the system. The second category are the safety related requirements. After this technique, the system is broken down into the different components. These different components all have their own function and are extensively described as a process. The steam system itself is split up into the steam system and a water system.

The methodology of using functional requirements also comes forward in other literature than named above. In sage and Armstrong (Sage & Armstrong, 1999) are the advantages discussed on decomposing a system into different functional components. A functional component is a component that has a function, but not necessarily a technique locked in for the components. By decomposing systems into functional components, alternative systems can be thought up and can lead to alternative systems. However, before the functions from the functional components can be rearranged, the system can be modelled into a flow diagram. For such a flow diagram, a functional analysis can be used to identify the different functions of the components. According to sage an Armstrong , 4 elements need to be addressed in every functional analysis:

1. The system needs to be hierarchical decomposed. The system needs to have a top function, which can be partitioned into sub functions.
2. In a functional analysis, the flows between the different components needs to be represented. These flows can contain information or physical items.
3. There can be information needed in a functional diagram to show/explain how a system can transform the input into the output.
4. The final aspect is that in a functional system can be shown how certain systems are controlled. Is a process repeated often or is it only used once in a certain amount of time. Also can this indicate that certain processes will not be operated whenever another process is started.

The last article that is discussed is the 17<sup>th</sup> chapter of the book “handbook of seismic risk analysis on management of civil infrastructure systems”. In this chapter is discussed on how to treat a system and what should be taken into account when designing a system. The article defines the system as “a set of interacting elements exhibiting closure and synergy”. With closure is meant that the system is distinguishable from the environment, and with synergy is meant that the system as a whole is more than the sum of the parts. The article explains systems thinking as followed “systems thinking not only studies the part of the system, but also the relationship between them, thus incorporating concepts such as wholes, parts, hierarchy of sub systems and emergent properties”. The system has a purpose and is designed as a whole.

These aspects are interesting to take into consideration when designing a framework which will compare systems. There are several aspects that will be taken into account when the system is designed in the framework. The goal of the design is to break down the system in parts that can be compared.

## Appendix 2: Risk reduction

The text discusses on how the risks should be reduced. This is a more elaborate discussion on why and how the risks are reduced and transformed. Two techniques are discussed in this appendix. The first is why and how the risks are reduced. The second aspect is why and how the risks scores are transformed.

### Risk reduction

#### Why?

In the case study came forward that certain components received much more risks than other components. This would lead to higher risk scores than expected. The choice is made to reduce the amount of risks to capture possible differences because of the sheer amount of risks. When reducing the risks. There are two aspects that are taken into account. The first one is the amount to which the risks are reduced, this amount is set on three.

The second aspect is that important risks could be left out by the reduction of the risks. Therefore, the risks with a score higher than the half of the maximum score(25), are always taken into the next technique. This means the risks with a score of 13 or higher are always taken into the next technique.

#### How?

The risks are reduced to three unless important risks would be left out of the further analysis. The choice is made that the half of the maximum score is important enough to take into account. Since the maximum score is 25. Every risk with a score of 13 or higher will be taken into the further analysis. SO in the end every risk with a score of 13 or higher will be taken into account for future techniques. If this is not the case. The three highest risks will be taken with for the future techniques.

### Risk transformation

#### Why?

Since the risks are calculated with the sum of two factors (likelihood and impact). The risk scores give a quadratic image of the risks. This is not optimal to read, therefor the risk scores are normalized. The goal is to give the risks a score between 0-1.

#### How?

For this the score of the risks is added to each other and divided by the maximum score. This is done with the square roots of the scores. This is explained in the formula below. In the formula,  $K_i$  is the risk score of the risks that are left from the selection above.  $K_{max}$  is the maximum amount of risk score a risk can have.

$$\frac{\sqrt{\sum K_i}}{\sqrt{\sum K_{max}}} = \text{Normalized, square root reduced, risk score}$$

## Appendix 3: System setup

In this chapter will be described how a combined steam from natural gas and electricity will probably look like. The system will be approached from two different angles. The first approach will focus on the creation of a network from scratch, whereas the second approach will focus on an existing steam producer that can expand its system with an electrical boiler.

The goal of the chapter is to have demarked the system and have the components to be used in the further techniques of the thesis. First will be discussed what the system needs to be able to do and what is necessary for that. The second part will discuss what the external flows are for the system to be functional. The last part will then discuss on how the system will be broken down in different components. The result will be that the system is broken down into components. This system should be able to be used in the further techniques of the research.

### Part 1: Functional requirements

On a system level the system needs to be able to transform natural gas and electricity to steam. The second part is that the system needs to transport the steam to the clients. The goal of this chapter is to have clear what the function is of each part of the system, this can be useful for the responsibilities each party can have in further techniques of the research.

### System boundaries

The system has several boundaries which have inputs and outputs. It can be expected that in the port of Rotterdam, the availability of these resources is there and few problems will be expected to have the resources available. The line will be drawn on the areas where there is only one party that can own a certain aspect (gas input, electricity input or emission output). Or where there are many different parties that can take part in the system and there is little specification to the ownership (steam clients). The goal is to reduce the design space so the system will be as simple as possible but functional.

### Natural gas input.

The input of the natural gas will be done probably through a contract with GTS. GTS will connect through the system and a contract will be made. The quality, capacity and odor of the gas will be taken into account. GTS will also take the gas to the correct location. This input is arranged with an contract, but can provide challenges for the system with certain setups.

### Electricity input

The electricity input will come with certain qualities, the system **will** require a large amount of energy and has industrial appliances, so it can be expected that the system will make use of the high voltage grid. It is the responsibility of the system operator that they will connect the system to the grid. This input is arranged with an contract, but can provide challenges for the system with certain setups.

### Steam output

For the steam output, clients will have requirements for the steam. A certain temperature and pressure will have to be maintained for the clients. Also needs the steam to be on the location of the clients. The third aspects is that the steam needs to be available whenever the clients need it.

### Water input

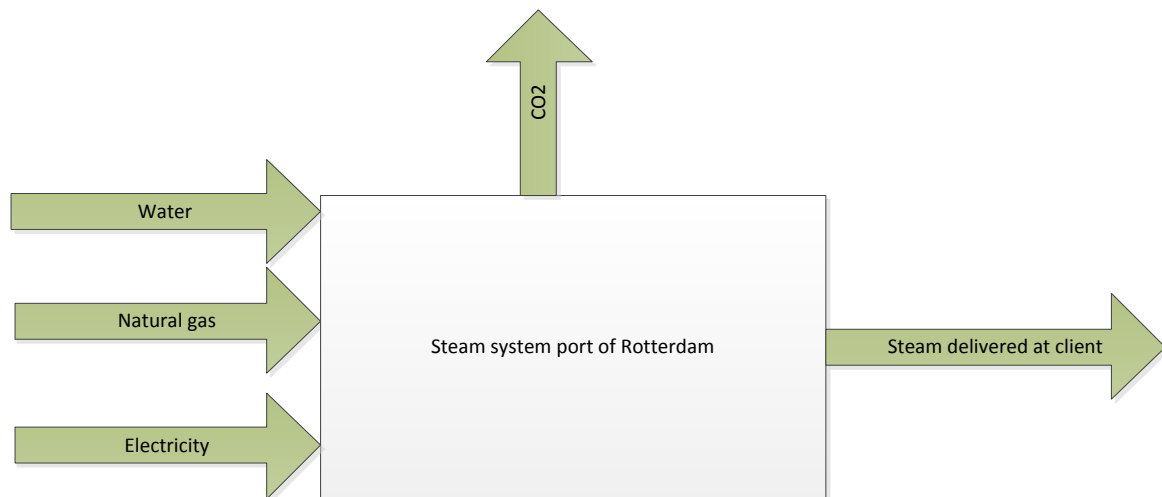
For the creation of steam, a supply of demineralized water is necessary. For this can an installation be build. In the industrial area of the port of Rotterdam, it can be expected that demi water is

available. This is something that needs a contract and where risks are involved. At this phase an external water flow into the system will be sufficient.

#### Emission output

The system will burn natural gas and this will produce CO<sub>2</sub> emissions. The system will have to make contracts for this and will have to have the right to emit this CO<sub>2</sub> System setup:

This will have as the first phase that the system will have 5 flows with the world outside of the system. Thus so far will the system look like below. In the next techniques we will discuss on how the system itself will be broken down.



**Figure 18: Defined steam system**

## Part 2: System breakdown

The system breakdown will consist of four main aspects. The transformation of gas to steam(gas boiler), the transformation of electricity to steam(electrical boiler), the transportation of the steam and as last the communication between the two transformation systems. Steam networks are usually made to fit and optimized into their location. Therefore choices have to be made what will be important for the system and what should be left outside of the scope.

### Gas to steam transformation

The gas to steam transformation will be done through an industrial gas boiler. This is the standard in the industry. The whole system will be treated as one component, so there will not be elaborated on what kind of boiler would be used. The option of a steam turbine can even be discussed, but in the thesis will be the focus on a system with a gas boiler.

The main aspects of the boiler will be to transform water into steam. This will be the main function of this component. One of the aspects in a gas boiler is that the boiler will emit CO<sub>2</sub>. There will be contracts necessary for this. The CO<sub>2</sub> can only be emitted with the corresponding emission trade permits. The goal is to produce the steam with as much efficiency as possible, but this is not the function of the system. So this will not be taken into account. At last there need to be a location for the installation and a connection with the input and output of the system.

### Electricity to steam transformation

For the creation of steam from electricity, an electrical steam boiler will be used. This will be the investment in the steam system that is designed. What should be noted about an electrical boiler, is that it transforms water into steam by the use of electricity.

### Steam transportation

The transportation will have several components in the system. Since the steam can be transported on several places in the system. The transportation can also require stations to keep the steam pressurized. There is a chance that the transportation components will have an crucial factor. Therefor the system will take the different transportation techniques into account and they will possibly be reduced in the system setup phase.

### Combining the two steam flows.

The combining of the two steam flows will consist of a simple valve which will integrate the two steam flows together. This aspects will however also take the responsibility to have the correct steam output for the clients. So this component will both take into account the combination of the two steam flows as well as de delivery to the clients.

For the delivery to the clients should be take into account that the different clients will have different demands for the steam. It is important to tune the different demands of the clients within the steam supply. This will be taken into account within the system. Since the delivery of the steam lies within the scope, this will be take into account with the electrical boiler and the gas boiler.

### Condensing steam.

IN a steam system it is common practice to reuse the water that has been used for the steam. For this will a condenser be implemented. With this, only a fraction of the water that usually would be necessary is needed for the steam system. Water is also only a fraction of the costs compared to natural gas and electricity, thus is could be argued to be left outside of the scope. Since water does not have the balancing issues and is a relatively cheap commodity, water input will be left outside the scope and the condenser will capture this part of the system in the risks.

## Conclusi

From the system can be expected that there are five main aspects that are important. These five aspects will be combined in the system. For every part in the system applies that it needs a permit for the activities that they will perform and a permit for the location that is filled. Whereas this project can be considered as a supporting project for renewable energy sources, it is expected that none of these components will

### *Functional requirements components*

In table 3 are the functional requirements identified for each of the components. The functional requirements are the tasks that a component needs to fulfill. Whenever the component itself fails, it will not be able to perform the function it is required to do. The functional requirements can be used in the risk identification technique. Since each risk should have an effect on one of these functions of the components.

**Table 6: functional requirements components.**

| No |                                          | Functions                                                                                                                                                                                                                                                                                |
|----|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Gas boiler                               | <ul style="list-style-type: none"><li>- Transform gas into steam</li><li>- Have steam available whenever it is needed</li><li>- Contract with gas supplier</li><li>- Contract to emit CO2</li><li>- Natural gas connection</li><li>- Water available when necessary</li></ul>            |
| 2  | Transportation steam from GB to Combiner | <ul style="list-style-type: none"><li>- Transport steam from a to b</li><li>- Connect with both points</li><li>- Deliver with sufficient quality</li></ul>                                                                                                                               |
| 3  | Electrical boiler                        | <ul style="list-style-type: none"><li>- Transform electricity into steam</li><li>- Have steam available whenever it is needed</li><li>- contract with electricity supplier</li><li>- Electricity connection</li><li>- water available when necessary</li><li>- location permit</li></ul> |
| 4  | Transportation steam from EB to Combiner | <ul style="list-style-type: none"><li>- Transport steam from a to b</li><li>- Connect with both points</li><li>- Deliver with sufficient quality</li></ul>                                                                                                                               |
| 5  | Steam combiner                           | <ul style="list-style-type: none"><li>- Combine two steam flows</li><li>- deliver sufficient amount of steam to clients</li><li>- make sure the quality is the steam is sufficient</li><li>- Communicate about demand from two steam suppliers</li><li>-</li></ul>                       |
| 6  | Transportation steam combiner to clients | <ul style="list-style-type: none"><li>- Transport steam from a to b</li><li>- Connect with both points</li><li>- Deliver with sufficient quality</li></ul>                                                                                                                               |
| 7  | Used steam transportation to condenser   | <ul style="list-style-type: none"><li>- Transport steam from a to b</li><li>- Connect with both points</li></ul>                                                                                                                                                                         |
| 8  | Condenser                                | <ul style="list-style-type: none"><li>- Transform steam into water</li><li>- take in used steam from clients</li><li>- contract with gas supplier</li><li>- Use energy gained?</li></ul>                                                                                                 |
| 9  | Water transportation to boilers.         | <ul style="list-style-type: none"><li>- Transport water from a to b</li><li>- Connect with both points</li><li>- Deliver with sufficient quality</li></ul>                                                                                                                               |

## Appendix 4 Workshop document

Dit is het document van de workshop van 11 februari 2015. In eerste instantie zal worden toegelicht hoe ik mijn scriptie heb opgesteld. Vervolgens zullen we een onderdeel van het raamwerk onder de loep nemen. Hiermee zal de informatie worden verzameld waarmee de case study kan worden uitgevoerd en kan worden getest.

### Doel van de workshop

Het doel van de workshop is om het raamwerk te testen aan de hand van een case study.

### Deelnemers:

Guy, Patrice, Jolt en Kasper

### Begrippen:

**Systeem:** het hele systeem van het omzetten van elektriciteit naar stoom.

**Component:** een blokje in het systeem

**Configuratie:** een systeem waarbij de verschillende componenten zijn verdeeld onder verschillende eigenaren

**Eigenaarscluster:** Alle componenten die onder 1 eigenaar vallen

### Case study

De case study gaat over een stoom systeem in de haven van Rotterdam, waarbij het huidige stoom systeem kan worden aangepast met een extra elektrische boiler. De elektrische boiler maakt het mogelijk om goedkope piekstroom te gebruiken voor het genereren van stoom. Er zijn verschillende manieren mogelijk waarop een dergelijk systeem kan worden ingericht. Hiervoor zal het systeem in componenten worden onderscheiden en zullen er verschillende eigenaars aan de componenten worden toebedeeld.

#### \*Raamwerk

Het raamwerk bestaat uit drie fases. Het doel van de workshop is de informatie te verzamelen uit het laatste gedeelte van de eerste fase en de tweede fase. De derde fase zal pas na de workshop worden uitgevoerd.

#### Fase 1

Fase 1 gaat over het neerzetten van het systeem en configuraties creëren. Dit is al gebeurd voorafgaand aan de workshop en het systeem is afgebakend en opgedeeld in componenten. Uiteindelijk ziet het systeem eruit als in figuur 1.

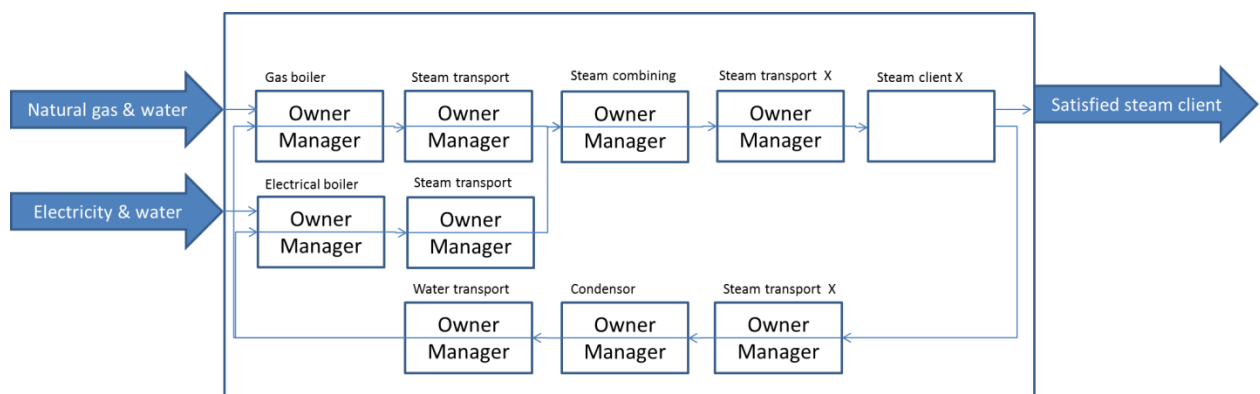


Figure 19: Decomposed system

In fase 1 worden configuraties opgesteld nadat het systeem is vastgesteld en componenten zijn geïdentificeerd. Deze configuraties zijn tot stand gekomen door een aantal situaties te schetsen die reëel worden geacht door experts.

Uiteindelijk worden er drie configuraties vergeleken met elkaar.

1. Er was een oorspronkelijk gas systeem waar 1 eigenaar het hele gas system in eigendom en beheer had. Nu komt er een derde partij die stoom wil leveren uit elektriciteit.

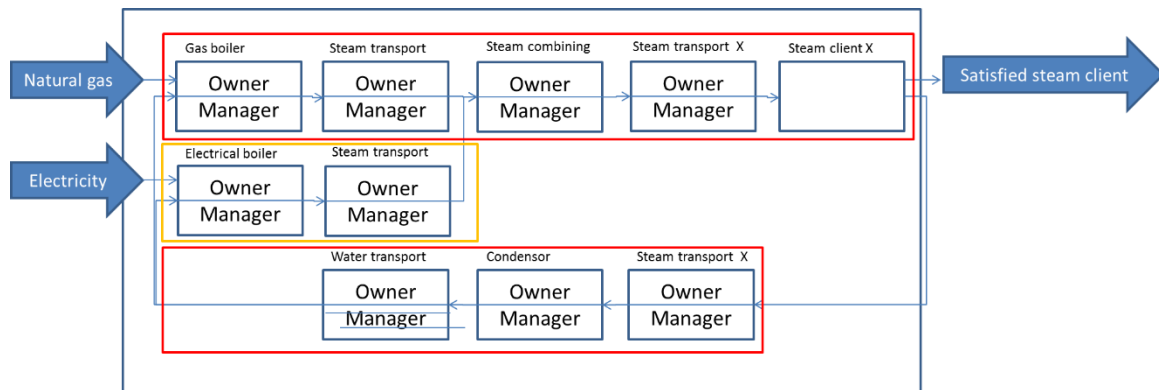


Figure 20: Configuration 1

2. De gas en elektrische boiler worden beheerd en zijn eigendom van een aparte eigenaar.

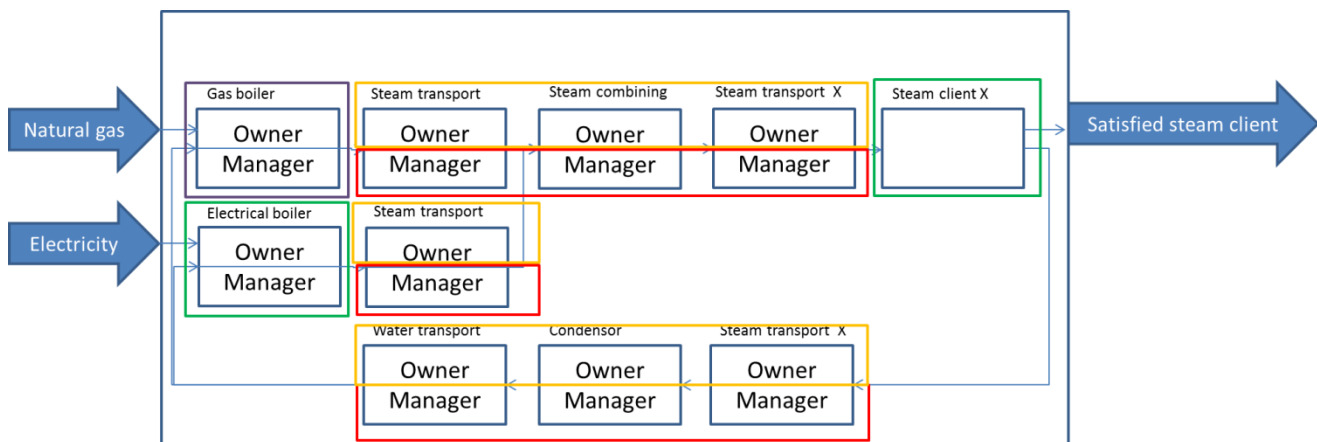
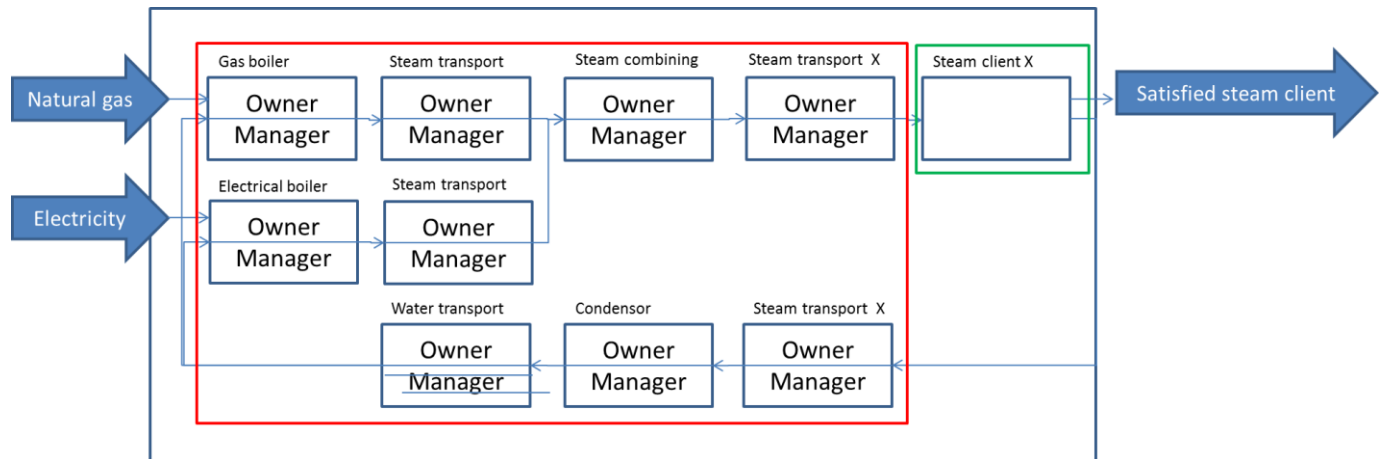


Figure 21: Configuration 2

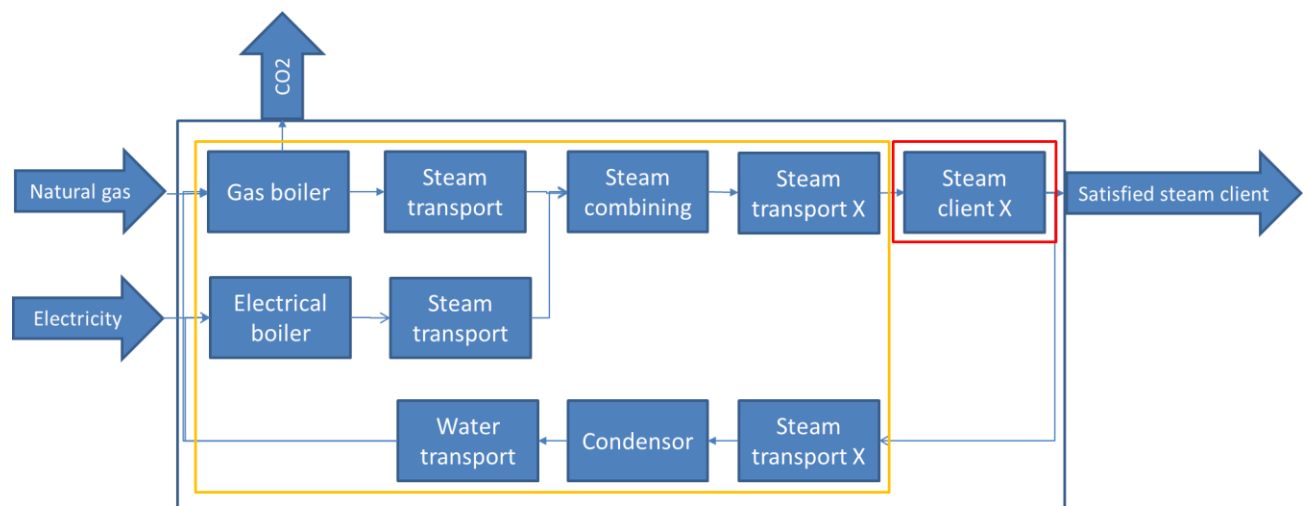
3. Het hele system is eigendom van 1 eigenaar, alleen de cliënten zijn een andere eigenaar.



**Figure 22: Configuration 3**

### Configuration 3

- The last ownership configuration is that there is already a steam system based on natural gas. This system is owned by 1 party. Another party enters the system with an electrical boiler and will supply cheaper steam whenever the electricity based steam is cheaper than the natural gas based steam



## Fase 2

### Deel 1

Fase twee is gericht op twee delen. Allereerst is er de risico identificatie stap. In het systeem zijn er belangrijke onderdelen (boilers, combineren van stoom, stoom afnemers) en minder flexibele onderdelen (pijpleidingen). **Het doel van de workshop is dat de deelnemers kijken naar de verschillende componenten die vallen onder een eigenaar en kijken wat de risico's zouden zijn als je als een component deze eigenaar zou hebben.** Uiteindelijk is het een doel om een aantal (3) belangrijkste risico's te hebben bij de hoofdcomponenten.

De deelnemers krijgen post-its en kunnen deze plakken op de verschillende configuraties die zijn opgehangen in de ruimte. Met de post-its kunnen ze aangeven welk risico ze willen aankaarten bij een component. Het doel zal zijn om van alle componenten de grootste risico's aan te geven. De focus ligt minder op het identificeren van alle risico's van een bepaalde component.

### Deel 2

Als er nog tijd over is kijken we naar de effecten van de risico's. Hierbij zal er iets anders worden gekeken naar de risico's dan normaal. Normaal wordt er de formule gebruikt:  $\text{Risico score} = \text{kans} * \text{impact}$ . Echter zal in dit raamwerk de impact worden opgesplitst in vijf verschillende typen impact. Er zal worden gekeken naar de TECOP impact (technisch, economisch, Commercieel, operationeel en politiek). Hierdoor zullen per risico zes scores worden gegeven.

## Fase 3

Fase drie zal zich focussen op het vergelijken van de verschillende configuraties, Dit zal niet in de workshop worden behandeld, maar achteraf worden doorgevoerd.

## Indeling workshop:

OM de workshop goed te laten verlopen is er een planning gemaakt. Deze planning bestaat uit een aantal punten die zullen worden doorgewerkt.

- 1: uitleg scriptie 10 minuten
- 2: uitleg systeem en configuraties 10 minuten.
- 3: risico's per configuratie. 55 minuten:
- 4: waarden voor alle risico's worden opgesteld 40 minuten:
- 5: kleine enquête achteraf over het raamwerk 5 minuten:

## Uitgebreide doorloop workshop

### 1: uitleg scriptie 15 minuten

- Uitleggen wat de probleemstelling is en hoe we van een stoom infrastructuur op een methodiek raamwerk zijn gekomen.
- Wat houdt het framework precies in en hoe is het opgebouwd.
- De kern van het framework gaat erom om eigenaarsmodellen met elkaar te vergelijken en dus te kijken naar wat de specifieke risico's zijn van een systeem waarin verschillende eigenaars configuraties mogelijk zijn.
- Een eigenaarsconfiguratie is mogelijk als verschillende onderdelen van een system in bezit kunnen zijn van verschillende partijen.
- Vergelijken van verschillende configuraties wordt ook gedaan in ene kosten baten analyse, echter wordt er in een kosten baten analyse gebruik gemaakt van een financiële incentive. In dit raamwerk wordt er gebruik gemaakt van risico's. Dit heeft twee redenen: ten eerste zorgen de risico's ervoor dat de output van de verschillende systemen niet alleen op financieel oogpunt worden getest. Hierdoor kunnen complicatie die moeilijk financieel kunnen worden meegenomen, makkelijker worden meegenomen. Ten tweede is er een component risico analyse in de planning, waarbij de risico's op verschillende aspecten zullen worden getest. Hierdoor kan het systeem ook worden vergeleken op verschillende aspecten wen kan er zo mogelijk meer informatie worden verkregen uit het system.
- Ook zijn de risico's gekoppeld aan 1 of meerdere componenten. Hierdoor kan er worden gekeken naar op welke niveau van het systeem de meeste risico's zijn en of de risico's tussen bepaalde componenten dezelfde aard hebben.

## Thesis content

|                        |            |                              |
|------------------------|------------|------------------------------|
| Develop generic method | Techniques | Method applied on Case study |
| Scientific added value |            |                              |

Figure 23: Slide on reserach structure Stedin

# Generic method

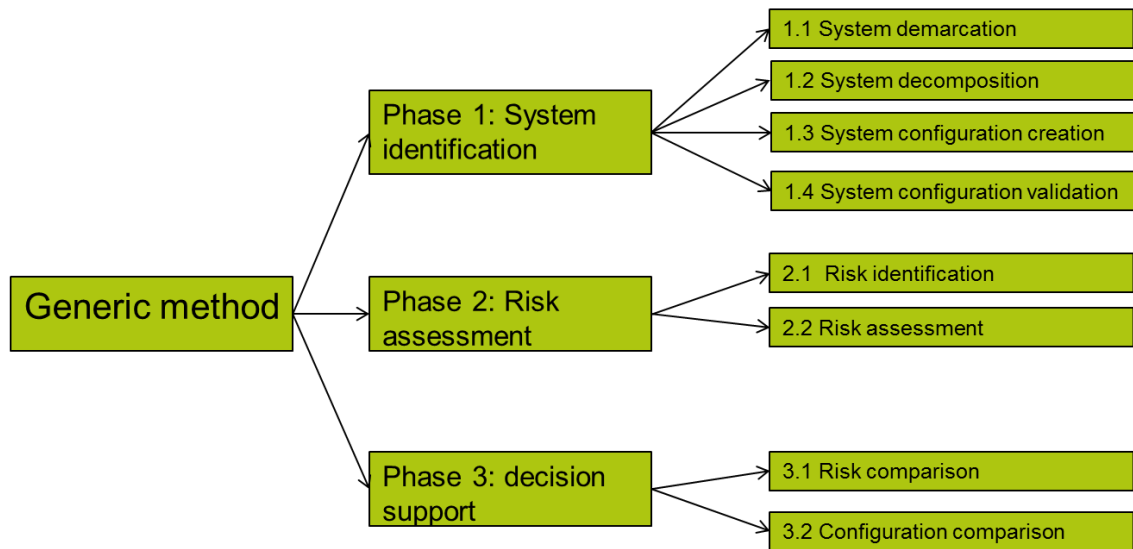


Figure 24: ROA description Stedin

# Generic method

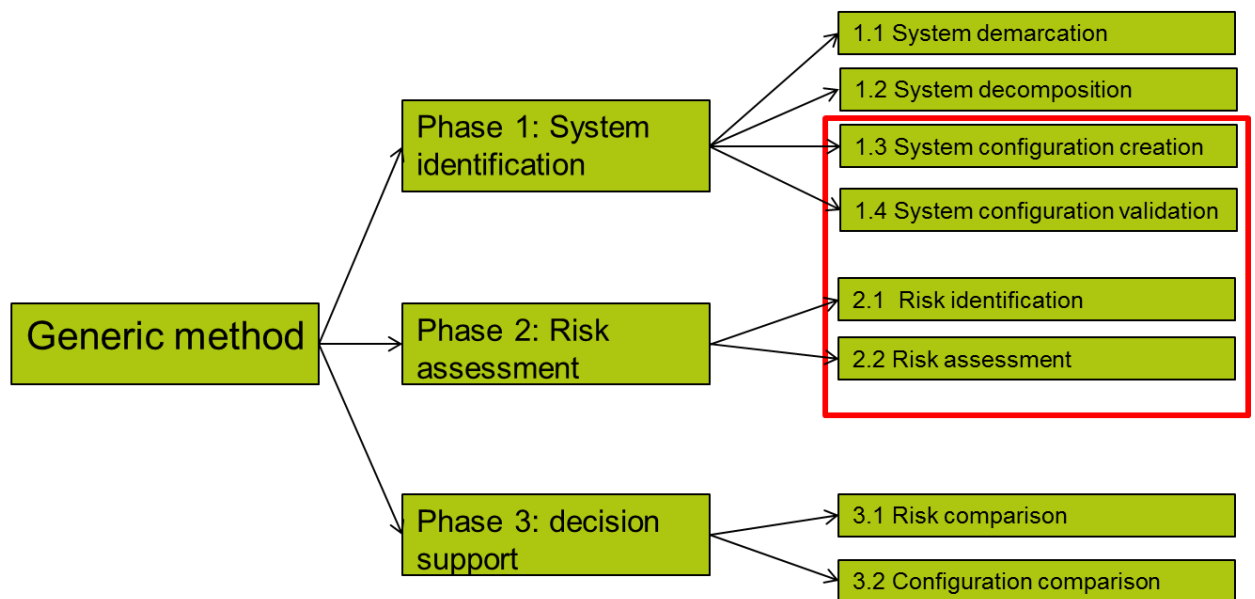


Figure 25: Focus workshop Stedin

2: uitleg systeem en configuraties 15 minuten.

- Systeem wordt uitgelegd aan de hand van het plaatje
- Boilers, combineren van stoom en afnemers zijn de belangrijkste componenten
- De pijpleidingen hebben minder prioriteit
- Er zijn 3 configuraties en de configuraties hebben 4 hoofd onderdelen en 5 sub onderdelen. Per hoofdonderdeel willen we 3 risico's en voor de kleinere onderdelen willen we er 1. Als we er dus naar kijken willen we  $4 \times 3 \times 3 = 36$  risico voor de grote onderdelen en  $5 \times 3 = 15$  voor de kleine onderdelen. Het is dus 51 risico's

- Configuraties worden uitgelegd aan de hand van de gedachten en worden gepresenteerd op a3 formaat.

3: risico's per configuratie: 15minuten:

De risico's per configuratie zullen worden geïdentificeerd aan de hand van vijf verschillende categorieën. De TECOP methode geeft hier een duidelijk lijn in. Keuze hier voor alle configuraties door elkaar of structuur? We gebruiken de TECOP methode om de risico's per categorie te identificeren.

Per risico worden er dus twee dingen geïdentificeerd.

1. Over wat voor risico praten we hier
2. Op welke componenten heeft het risico invloed.

Risico's worden aangegeven met postits

4: waarden voor alle risico's worden opgesteld en wordt gewoon snel ingevuld 40 minuten.

Met alle risico's wordt er gekeken naar op welke aspecten het systeem

Dus per risico wordt de kans ingedeeld: dit is een generieke indicatie tussen 1-5

Verder wordt de impact bepaald door de impact van vijf categorieën te bedenken: Technisch, economisch, operationeel, commercieel en politiek.

5: Enquete

Als laatste stap wordt er nog een kleine enquête gehouden met wat de deelnemers van het raamwerk vonden en of ze dit als nuttig zien. Zo nee, hoe zou het wel als nuttig kunnen worden gemaakt.

## Appendix 5: results case study:

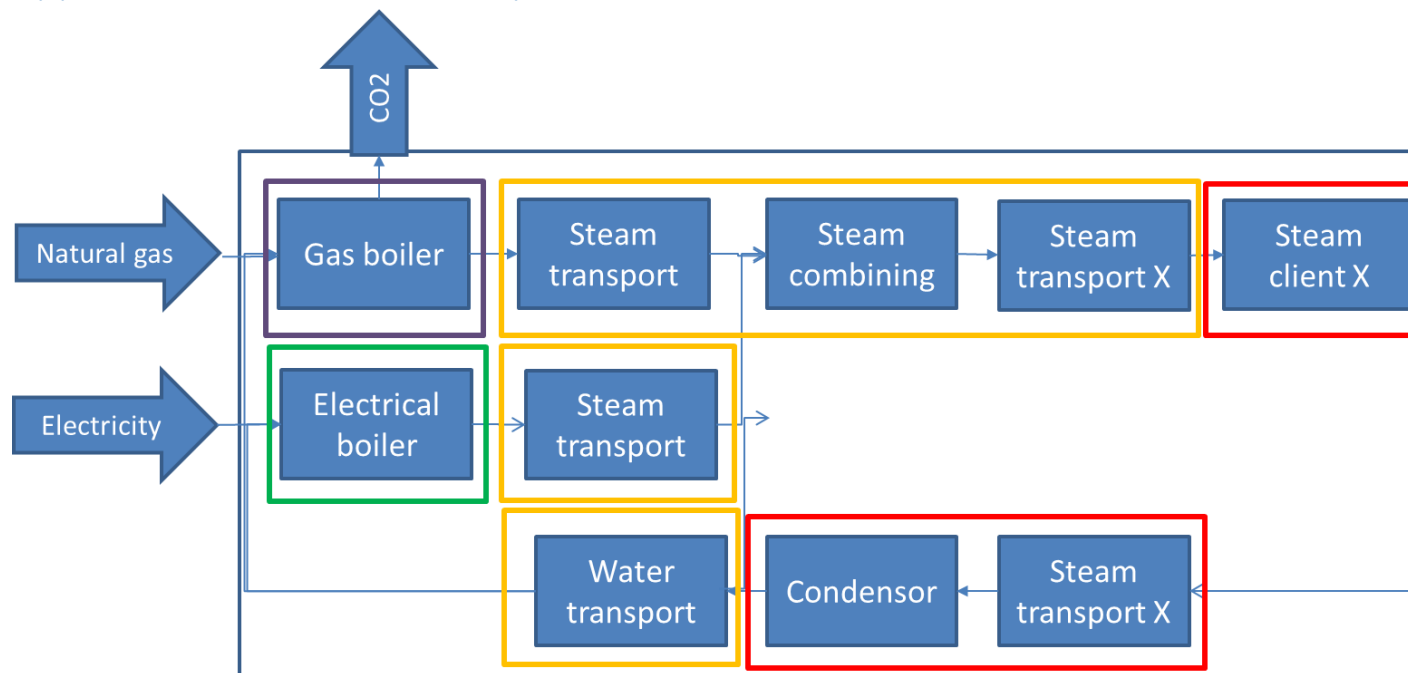


Figure 26: Configuration 1

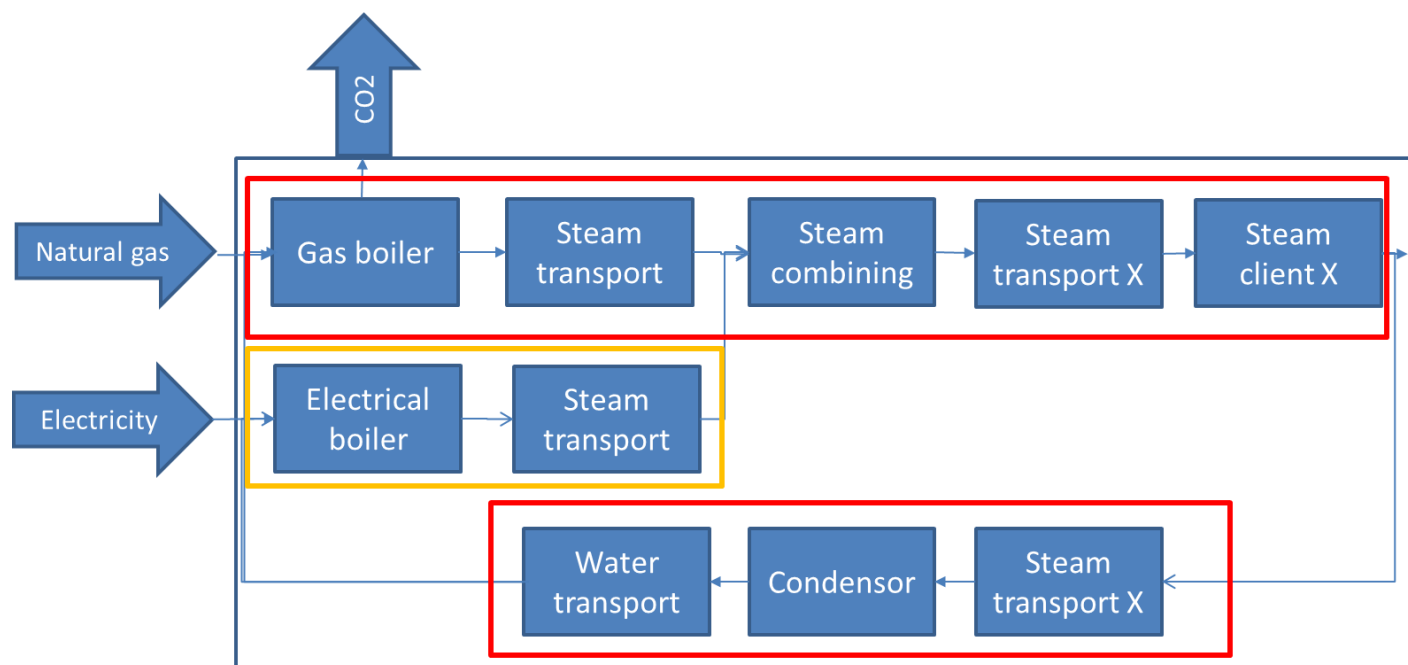


Figure 27: Configuration 2

**Table 7: Risks Configuration 1**

|           | Component | Omschrijving risico                                                                                                                                             | Eigenaar | TECOP | Kans | Impact | risk score |
|-----------|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-------|------|--------|------------|
| Risico 1  | 1         | The electricity price becomes lower and the steam produced by electricity is cheaper than the steam producer by natural gas. There is a negative spark          | 1        | c     | 2    | 5      | 10         |
| Risico 2  | 1         | Gas has less buying flexibility than electricity, this means that the gas boiler could have the problem that it cannot deliver steam whenever it is asked.      | 1        | o     | 4    | 2      | 4          |
| Risico 3  | 1         | gas is finished                                                                                                                                                 | 1        | p     | 1    | 5      | 4          |
| Risico 4  | 1         | CO2 price is rising through policy measures.                                                                                                                    | 1        | p     | 3    | 3      | 9          |
| Risico 5  | 1         | The transport is unreliable and there is much outage in the system                                                                                              | 1        | o     | 1    | 5      | 5          |
| Risico 7  | 1         | The operational costs of the gas boiler become higher because the gas boiler has to deal with more fluctuations, which had not been a problem in the past.      | 1        | p     | 2    | 2      | 6          |
| Risico 8  | 2         | The gas boiler is not operating enough. This makes this component unprofitable as an investment                                                                 | 1        | e     | 1    | 1      | 9          |
| Risico 9  | 3         | Pressure differences occur because of the switching between the different steam flows                                                                           | 1        | o     | 2    | 1      | 4          |
| Risico 10 | 3         | Disagreement on the measurements in the system with different parties. The risk is located here because this party executes the measurements                    | 1        | p     | 3    | 1      | 3          |
| Risico 11 | 3         | Damage on the system is directed to another party than the system operator. So another party is blamed for damage to the system.                                | 1        | c     | 2    | 2      | 6          |
| Risico 12 | 3         | There are risks couple with the delivery demands with the e-boiler                                                                                              | 1        | o     | 4    | 1      | 4          |
| Risico 13 | 3         | the quality of the steam from the different boilers is not the same                                                                                             | 1        | o     | 2    | 2      | 3          |
| Risico 14 | 5         | Condensate is not accepted by the E-boiler                                                                                                                      | 1        | t     | 2    | 1      | 2          |
| Risico 15 | 5         | The transport is unreliable and there is much outage in the system                                                                                              | 1        | t     | 1    | 3      | 3          |
| Risico 16 | 5         | The quality of the steam from the different boilers is not the same                                                                                             | 1        | t     | 2    | 3      | 6          |
| Risico 17 | 6         | The electricity price becomes higher and the steam produced by electricity is more expensive than the steam producer by natural gas. There is a positive spark. | 2        | p     | 2    | 5      | 15         |
| Risico 18 | 6         | The electrical boiler subordinate to the big user of the system. The main user can decide to take off steam of you.                                             | 2        | c     | 4    | 4      | 16         |
| Risico 19 | 6         | An electrical system is more vulnerable for outages and will age faster                                                                                         | 2        | t     | 2    | 2      | 4          |
| Risico 20 | 6         | The quality of the condensate is too low. Extra investment are needed to get the quality on the right level.                                                    | 2        | o     | 2    | 2      | 4          |
| Risico 21 | 6         | The transport is unreliable and there is much outage in the system                                                                                              | 2        | t     | 1    | 4      | 4          |
| Risico 22 | 6         | One of the steam clients goes bankrupt.                                                                                                                         | 2        | o     | 1    | 5      | 4          |
| Risico 23 | 6         | The E-boiler is not operational and a large capacity fee has to be paid for the electricity connection.                                                         | 2        | c     | 2    | 3      | 9          |
| Risico 24 | 7         | The electrical boiler is not operating much. This makes this component unprofitable as an investment                                                            | 2        | e     | 2    | 3      | 6          |
| Risico 25 | 8         | Quality condensate is low and leads to rapid aging of the system                                                                                                | 1        | o     | 2    | 2      | 4          |

**Table 8: Risks configuration 2**

|                  | Component | Risk description                                                                                                                                                | Owner | TECOP |
|------------------|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------|
| Risico 1         | 1         | Gas has less buying flexibility than electricity, this means that the gas boiler could have the problem that it cannot deliver steam whenever it is asked.      | 1     | O     |
| Risico 2         | 1         | The transporter of the steam will demand more money from the suppliers. This leads to possible less profit for the gas boiler owner                             | 1     | C     |
| Risico 3         | 1         | CO2 price is rising through policy measures.                                                                                                                    | 1     | P     |
| Risico 4         | 1         | Gas is finished                                                                                                                                                 | 1     | O     |
| <b>Risico 12</b> | 3         | One of the steam clients goes bankrupt.                                                                                                                         | 2     | C     |
| Risico 4         | 1         | The electricity price becomes lower and the steam produced by electricity is cheaper than the steam producer by natural gas. There is a negative spark          | 1     | C     |
| Risico 5         | 1         | The transport system breaks down and the gas boiler has no costumers.                                                                                           | 1     | O     |
| Risico 6         | 1         | The costumer makes a deal with the electrical boiler. This leaves the gas boiler out of business. Reasons for this could be sustainable production of steam.    | 1     | C     |
| Risico 7         | 1         | The operational costs of the gas boiler become higher because the gas boiler has to deal with more fluctuations, which had not been a problem in the past.      | 1     | O     |
| Risico 8         | 1         | The quality of the condensate is too low. Extra investments are needed to get the quality on the right level.                                                   | 1     | O     |
| Risico 9         | 2         | The gas boiler is not operating enough. This makes this component unprofitable as an investment                                                                 | 2     | E     |
| Risico 10        | 3         | The different qualities of the different steam flows are not aligned. Extra techniques have to be taken to integrate the two steam flows                        | 2     | C     |
| Risico 11        | 3         | Pressure differences occur because of the switching between the different steam flows                                                                           | 2     | O     |
| <b>Risico 12</b> | 3         | One of the steam clients goes bankrupt.                                                                                                                         | 2     | C     |
| <b>Risico 13</b> | 3         | Disagreement on the measurements in the system with different parties. The risk is located here because this party executes the measurements                    | 2     | O     |
| Risico 14        | 3         | Costumer and producer cut out transporter and deliver steam on their own network.                                                                               | 2     | E     |
| Risico 15        | 3         | The producers negotiate fixed (too high) prices for transport.                                                                                                  | 2     | c     |
| Risico 16        | 5         | Condensate is not accepted back. The costumer delivers the wrong quality condensate back to the system.                                                         | 3     | o     |
| Risico 17        | 5         | The costumer is held responsible for damage done in the transport network. For instance, suddenly opening all valves.                                           | 3     | o     |
| Risico 18        | 5         | The transport is unreliable and there is much outage in the system                                                                                              | 3     | t     |
| Risico 16        | 5         | The quality of the steam from the different boilers is not the same                                                                                             | 1     | t     |
| Risico 20        | 5         | The middlemen parties ask a too big margin for the steam.                                                                                                       | 3     | c     |
| Risico 21        | 6         | The electricity price becomes higher and the steam produced by electricity is more expensive than the steam producer by natural gas. There is a positive spark. | 4     | p     |
| Risico 22        | 6         | The E-boiler is not operational and a large capacity fee has to be paid for the electricity connection.                                                         | 4     | c     |
| <b>Risico 12</b> | 3         | One of the steam clients goes bankrupt.                                                                                                                         | 2     | c     |
| Risico 23        | 6         | An electrical system is more vulnerable for outages and will age faster.                                                                                        | 4     | t     |
| Risico 24        | 6         | The quality of the condensate is too low. Extra investment are needed to get the quality on the right level.                                                    | 4     | o     |
| Risico 25        | 6         | The costumer will work together with the gas boiler. This leads to less sales.                                                                                  | 4     | c     |
| Risico 26        | 7         | The electrical boiler is not operating much. This makes this component unprofitable as an investment                                                            | 2     | e     |
| Risico 27        | 8         | Quality condensate is low and leads to rapid aging of the system                                                                                                | 2     | o     |

## Configuration 1

**Table 9: Risk scores configuration 1**

| Criteria                            | Description component/owner/ risk                                                                                                 | Description on calculation                                                                 | Score |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-------|
| Total configuration score           |                                                                                                                                   | The risks scores of all the components are added into 1 total risk score                   | 1     |
| Score owner 1                       | The owner of the gas boiler. Only owns the gas boiler                                                                             | The risks scores of all the components owner by owner 1 are added into 1 total risk score. | 3     |
| Score owner 2                       | This owner owns the distribution system. The owner is responsible for the distribution and management of the grid.                | The risks scores of all the components owner by owner 2 are added into 1 total risk score. | 3     |
| Score owner 3                       | The clients of the steam. They buy the steam                                                                                      | The risks scores of all the components owner by owner 3 are added into 1 total risk score. | 1     |
| Score owner 4                       | The owner of the electrical boiler.                                                                                               | The risks scores of all the components owner by owner 4 are added into 1 total risk score. | 2     |
| Component 1                         | Gas boiler                                                                                                                        | The risk score of component 1                                                              | 3     |
| Component 2                         | Steam Pipeline                                                                                                                    | The risk score of component 2                                                              | 1     |
| Component 3                         | Steam combining piece of pipeline                                                                                                 | The risk score of component 3                                                              | 1     |
| Component 4                         | Steam Pipeline                                                                                                                    | The risk score of component 4                                                              | 0     |
| Component 5                         | Steam clients                                                                                                                     | The risk score of component 5                                                              | 1     |
| Component 6                         | Electrical boiler                                                                                                                 | The risk score of component 6                                                              | 2     |
| Component 7                         | Steam Pipeline                                                                                                                    | The risk score of component 7                                                              | 1     |
| Component 8                         | Steam pipeline                                                                                                                    | The risk score of component 8                                                              | 4     |
| Component 9                         | Condensor                                                                                                                         | The risk score of component 9                                                              | 0     |
| Component 10                        | Condense pipeline                                                                                                                 | The risk score of component 10                                                             | 0     |
| Risk #1                             | The risk that the gas boiler gets outcompeted by the electrical boiler through lower electricity prices and/or higher gas prices. | The highest scoring risk                                                                   | 1     |
| Risk #2                             | The risk that the electrical boiler gets outcompeted by the gas boiler through lower gas prices and/or higher electricity prices. | The second biggest risk of the ownership configurations:                                   | 1     |
| Risk #3                             | CO2 price is raised through policy measures                                                                                       | The third biggest risk of the ownership configuration.                                     | 9     |
| Risk #4                             | The middleman(owner 2) asks a too big margin for the steam delivered                                                              | The fourth biggest risk of the ownership configuration.                                    | 9     |
| Risk #5                             | The e-boiler is not operational and a large capacity fee has to be paid for the electricity connection with the e boiler          | The fifth biggest risk of the ownership configuration.                                     | 9     |
| Average score per component owner 1 |                                                                                                                                   | The average risk scores per component of owner 1                                           | 3     |
| Average score per component owner 2 |                                                                                                                                   | The average risk scores per component of owner 2                                           | 6     |
| Average score per component owner 3 |                                                                                                                                   | The average risk scores per component of owner 3                                           | 6     |
| Average score per component owner 4 |                                                                                                                                   | The average risk scores per component of owner 4                                           | 2     |

## Configuration 2

**Table 10: Risk scores configuration 2**

| Criteria                            | Description component/owner/ risk                                                                                                                               | Description on calculation                                                                 | Score |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-------|
| Total configuration score           |                                                                                                                                                                 | The risks scores of all the components are added into 1 total risk score                   | 9     |
| Score owner 1                       | The owner of the whole gas steam system                                                                                                                         | The risks scores of all the components owner by owner 1 are added into 1 total risk score. | 5     |
| Score owner 2                       | The owner of the electrical boiler and supply to the steam system.                                                                                              | The risks scores of all the components owner by owner 2 are added into 1 total risk score. | 3     |
| Component 1                         | Gas boiler                                                                                                                                                      | The risk score of component 1                                                              | 2     |
| Component 2                         | Steam Pipeline                                                                                                                                                  | The risk score of component 2                                                              | 1     |
| Component 3                         | Steam combining piece of pipeline                                                                                                                               | The risk score of component 3                                                              | 1     |
| Component 4                         | Steam Pipeline                                                                                                                                                  | The risk score of component 4                                                              | 0     |
| Component 5                         | Steam clients                                                                                                                                                   | The risk score of component 5                                                              | 1     |
| Component 6                         | Electrical boiler                                                                                                                                               | The risk score of component 6                                                              | 3     |
| Component 7                         | Steam Pipeline                                                                                                                                                  | The risk score of component 7                                                              | 6     |
| Component 8                         | Steam pipeline                                                                                                                                                  | The risk score of component 8                                                              | 4     |
| Component 9                         | Condensor                                                                                                                                                       | The risk score of component 9                                                              | 0     |
| Component 10                        | Condense pipeline                                                                                                                                               | The risk score of component 10                                                             | 0     |
| Risk #1                             | The electrical boiler subordinate to the big user of the system. The main user can decide to take off steam of you.                                             | The highest scoring risk                                                                   | 1     |
| Risk #2                             | The electricity price becomes higher and the steam produced by electricity is more expensive than the steam producer by natural gas. There is a positive spark. | The second biggest risk of the ownership configurations:                                   | 1     |
| Risk #3                             | The electricity price becomes lower and the steam produced by electricity is cheaper than the steam producer by natural gas. There is a negative spark          | The third biggest risk of the ownership configuration.                                     | 1     |
| Risk #4                             | CO2 price is rising through policy measures.                                                                                                                    | The fourth biggest risk of the ownership configuration.                                    | 9     |
| Risk #5                             | Gas has less buying flexibility than electricity, this means that the gas boiler could have the problem that it cannot deliver steam whenever it is asked.      | The fifth biggest risk of the ownership configuration.                                     | 8     |
| Average score per component owner 1 |                                                                                                                                                                 | The average risk scores per component of owner 1                                           | 3     |
| Average score per component owner 2 |                                                                                                                                                                 | The average risk scores per component of owner 2                                           | 6     |

### Configuration 1

| Criteria | Description component/owner/ risk | Description on calculation | Score |
|----------|-----------------------------------|----------------------------|-------|
|----------|-----------------------------------|----------------------------|-------|

**Table 11: Normalized risks configuration 1**

|                                     |                                                                                                                                                                 |                                                                                            |      |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|------|
| Total configuration score           |                                                                                                                                                                 | The risks scores of all the components are added into 1 total risk score                   | 1.53 |
| Score owner 1                       | The owner of the whole gas steam system                                                                                                                         | The risks scores of all the components owner by owner 1 are added into 1 total risk score. | 0,87 |
| Score owner 2                       | The owner of the electrical boiler and supply to the steam system.                                                                                              | The risks scores of all the components owner by owner 2 are added into 1 total risk score. | 0,67 |
| Component 1                         | Gas boiler                                                                                                                                                      | The risk score of component 1                                                              | 0,36 |
| Component 2                         | Steam Pipeline                                                                                                                                                  | The risk score of component 2                                                              | 0,04 |
| Component 3                         | Steam combining piece of pipeline                                                                                                                               | The risk score of component 3                                                              | 0,16 |
| Component 4                         | Steam Pipeline                                                                                                                                                  | The risk score of component 4                                                              | 0    |
| Component 5                         | Steam clients                                                                                                                                                   | The risk score of component 5                                                              | 0,15 |
| Component 6                         | Electrical boiler                                                                                                                                               | The risk score of component 6                                                              | 0,43 |
| Component 7                         | Steam Pipeline                                                                                                                                                  | The risk score of component 7                                                              | 0,24 |
| Component 8                         | Steam pipeline                                                                                                                                                  | The risk score of component 8                                                              | 0,16 |
| Component 9                         | Condensor                                                                                                                                                       | The risk score of component 9                                                              | 0    |
| Component 10                        | Condense pipeline                                                                                                                                               | The risk score of component 10                                                             | 0    |
| Risk #1                             | The electrical boiler subordinate to the big user of the system. The main user can decide to take off steam of you.                                             | The highest scoring risk                                                                   | 0,64 |
| Risk #2                             | The electricity price becomes higher and the steam produced by electricity is more expensive than the steam producer by natural gas. There is a positive spark. | The second biggest risk of the ownership configurations:                                   | 0.4  |
| Risk #3                             | The electricity price becomes lower and the steam produced by electricity is cheaper than the steam producer by natural gas. There is a negative spark          | The third biggest risk of the ownership configuration.                                     | 0.4  |
| Risk #4                             | CO2 price is rising through policy measures.                                                                                                                    | The fourth biggest risk of the ownership configuration.                                    | 0.36 |
| Risk #5                             | Gas has less buying flexibility than electricity, this means that the gas boiler could have the problem that it cannot deliver steam whenever it is asked.      | The fifth biggest risk of the ownership configuration.                                     | 0,32 |
| Average score per component owner 1 |                                                                                                                                                                 | The average risk scores per component of owner 1                                           | 0,11 |
| Average score per component owner 2 |                                                                                                                                                                 | The average risk scores per component of owner 2                                           | 0,33 |

**Table 12: Normalized risks configuration 2**

| Criteria                  | Description component/owner/ risk                     | Description on calculation                                                                 | Score |
|---------------------------|-------------------------------------------------------|--------------------------------------------------------------------------------------------|-------|
| Total configuration score |                                                       | The risks scores of all the components are added into 1 total risk score                   | 1.    |
| Score owner 1             | The owner of the gas boiler. Only owns the gas boiler | The risks scores of all the components owner by owner 1 are added into 1 total risk score. | 0.    |

|                                     |                                                                                                                                   |                                                                                            |   |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|---|
| Score owner 2                       | This owner owns the distribution system. The owner is responsible for the distribution and management of the grid.                | The risks scores of all the components owner by owner 2 are added into 1 total risk score. | 0 |
| Score owner 3                       | The clients of the steam. They buy the steam                                                                                      | The risks scores of all the components owner by owner 3 are added into 1 total risk score. | 0 |
| Score owner 4                       | The owner of the electrical boiler.                                                                                               | The risks scores of all the components owner by owner 4 are added into 1 total risk score. | 0 |
| Component 1                         | Gas boiler                                                                                                                        | The risk score of component 1                                                              | 0 |
| Component 2                         | Steam Pipeline                                                                                                                    | The risk score of component 2                                                              | 0 |
| Component 3                         | Steam combining piece of pipeline                                                                                                 | The risk score of component 3                                                              | 0 |
| Component 4                         | Steam Pipeline                                                                                                                    | The risk score of component 4                                                              | 0 |
| Component 5                         | Steam clients                                                                                                                     | The risk score of component 5                                                              | 0 |
| Component 6                         | Electrical boiler                                                                                                                 | The risk score of component 6                                                              | 0 |
| Component 7                         | Steam Pipeline                                                                                                                    | The risk score of component 7                                                              | 0 |
| Component 8                         | Steam pipeline                                                                                                                    | The risk score of component 8                                                              | 0 |
| Component 9                         | Condensor                                                                                                                         | The risk score of component 9                                                              | 0 |
| Component 10                        | Condense pipeline                                                                                                                 | The risk score of component 10                                                             | 0 |
| Risk #1                             | The risk that the gas boiler gets outcompeted by the electrical boiler through lower electricity prices and/or higher gas prices. | The highest scoring risk                                                                   | 0 |
| Risk #2                             | The risk that the electrical boiler gets outcompeted by the gas boiler through lower gas prices and/or higher electricity prices. | The second biggest risk of the ownership configurations:                                   | 0 |
| Risk #3                             | CO2 price is raised through policy measures                                                                                       | The third biggest risk of the ownership configuration.                                     | 0 |
| Risk #4                             | The middleman(owner 2) asks a too big margin for the steam delivered                                                              | The fourth biggest risk of the ownership configuration.                                    | 0 |
| Risk #5                             | The e-boiler is not operational and a large capacity fee has to be paid for the electricity connection with the e boiler          | The fifth biggest risk of the ownership configuration.                                     | 0 |
| Average score per component owner 1 |                                                                                                                                   | The average risk scores per component of owner 1                                           | 0 |
| Average score per component owner 2 |                                                                                                                                   | The average risk scores per component of owner 2                                           | 0 |
| Average score per component owner 3 |                                                                                                                                   | The average risk scores per component of owner 3                                           | 0 |
| Average score per component owner 4 |                                                                                                                                   | The average risk scores per component of owner 4                                           | 0 |

## Configuration 2

**The vision is to create a framework that is applicable on multiple fields. The framework takes both the technical aspects as well as the** How can the structure of other frameworks be translated for the structure to compare ownership models?

**institutional aspects into account of the system. The framework**

**Other wishes for the framework is that the framework is applicable in a reasonable time. This means that the speed will be taken into account in the different phases of the framework.**