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Cost Allocation and Risk Analysis

- Case study of increased heat integration within a Chemical Cluster.

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Abstract

The energy usage within the chemical cluster in Stenungsund was evaluated by Hackl et al. in a Chalmers report 2010. Subsequently, an improved heat integration system was proposed to optimize the fossil fuels usage and therefore lower the overall emissions by the cluster and cut energy costs. This thesis is the result of a case study and aims to evaluate the increased heat integration uncertainties and suggest a cost allocation model.

Sustainability and environmental awareness is acknowledged as being fundamental in today's society. Companies strive to remain their legitimacy on the marketplace and prevent future governmental regulations by keeping pace with technical and societal development.

The study is designed as a deductive case study. Data was collected through literature studies and interviews. Uncertainties are evaluated with a SWOT-analysis where strengths, weaknesses, opportunities and threats connected with the increased heat integration are determined. The results from the SWOT-analysis were considered in order to suggest alternative cost allocation models and different scenarios for further sensitivity analysis.

Summary of main findings: The results from the SWOT-analysis show that if the heat integration is implemented, according to a model suggested by Hart and Milstein (2009), the cluster's sustainable value would increase. From the SWOT-analysis it is also evident that the heat integration system is connected with many risks. However, risks and threats could be avoided or eased with an external third party or if the heat integration is only performed between two of the companies. In those cases the risks and economic benefits would decrease but the companies would still benefit from the enhanced sustainable value but with less cost savings.

The potential costs and benefits from the system show an unequal distribution amongst each company. However, using full costing calculation and an allocation base of potential energy savings, which is accepted by the representatives, levels the conditions.

Further, the findings in this study indicate that the improved heat integration is seen as a relatively simple technical solution and a cost saver by Chalmers Technical University, while the companies within the cluster is more skeptical and sees it as an expensive, risky investment which will make their production processes more complicated with the proposed system. These gaps in viewpoints have, in our opinion, led to the delay of implementing the system.

Keywords: Chemical Cluster, SWOT, Risk Management, Cost Allocation, Sustainability

Innehåll

1. Introduction

This chapter provides a foundation for understanding the background and purpose of this thesis. It starts with a brief background description, which leads to a problem discussion where the aim is presented.

1.1 Background

Sweden´s largest petrochemical cluster of its kind is located in Stenungsund. The companies within the cluster are: Borealis AB, AkzoNobel Sweden AB, INEOS Sweden AB, Perstorp OXO AB and AGA Gas AB. The cluster consumes around 5% of Sweden´s total fossil fuel usage and is currently one of Sweden's major emitter of carbon dioxide (Jönsson et al. 2012). The environmental aspect is more important in today's society and the cluster has adopted a common vision: "*Sustainable Chemistry 2030*". The vision states that the cluster should be based mainly on biogenic feedstock and renewable energy by 2030. One step towards realizing this vision could be to improve the energy efficiency within the cluster by increasing the heat integration for hot water, steam and internal excess fuels. Such a system would facilitate energy savings through increased heat exchange between the different plants and thereby provide energy savings for the cluster.

Our study is based on a previous Total Site Analysis (TSA), which was developed by *Chalmers University of Technology* in Gothenburg (Hackl et al. 2010). The TSA concluded that the cluster could save a considerable amount of fossil fuels through improved heat integration. The savings in opting out of a large amount of today's usage of fossil fuels would create economic and sustainable benefits for the cluster. However, the economic impact of such a system would benefit the companies unequally. Further, it is also likely that the system will increase the risks due to collaborating outside the companies own borders and the potential higher complexity of the production processes. However, the risks linked to the system will be examined and related to other options available.

1.1.1 Why is sustainability important?

Increased heat integration will provide enhanced energy efficiency and thereby also contribute to a more sustainable environment. Sustainability will in this thesis be defined as *"meeting our needs with not compromising the ability of future generations"* (Hart and Milstein, 2003, p. 56). Today´s turbulent world requires an adaption to a more sustainable production in order to stay competitive. Working towards a more sustainable society creates benefits for the economy, community and environment because pollutions and dirty production indicates an inefficient production (Schaltegger, et al. 2008). In a total efficient system, pollutions and waste would not be created, or would be converted into products with a market value. A clean production creates benefits such as more innovative, economically beneficial and competitive production.

With an investment in a common utility system for hot water, steam and internal fuels the cluster would lower the CO2-emissions, by reducing their energy use. If the companies succeed with installing the heat integration system it would lead to substantial cost savings. Further, the savings would generate higher shareholder value in the long run and improve the companies' environmental image.

1.1.2 Description of the Chemical Cluster

The cluster consists of five different chemical companies. AkzoNobel Sweden AB has a plant consisting of four different production plants and produce for example, ethylene oxide, amines and surfactants. AkzoNobel Sweden AB has two separate business units, present at the site in Stenungsund, Ethylene Amines AB and Surface Chemistry AB. INEOS Sweden AB is producing poly vinyl chloride (PVC). Perstorp OXO AB produces several different products and one of them is plasticizers. AGA Gas AB produces nitrogen and oxygen. Borealis AB is the largest company in the cluster, it has two plants in Stenungsund, one of them manufactures industrial products and the other one is a cracker plant. The cluster is already dependent of each other where Borealis AB is the heart and supplies the other companies with: ethylene, fuel gas, propylene and hydrogen. The companies do not directly compete with each other and the process plants are profiled against different business segments. However, some of the companies are competing with each other globally, at the parent company level.

The five companies within the cluster are all parts of large multinational organizations, with their headquarters located outside of Sweden. The parent companies approval is thus needed for important decisions and possible new investments.

1.1.3 Previous research

The benchmark for this paper is the TSA, which describes the improved heat integration and all energy measurements are performed by researchers on Chalmers University of Technology (Hackl et al. 2010). The production processes in chemical plants require large amounts of energy and produces excess heat as an industrial by-product. The process of heat integration aims to optimize the use of energy that is available within the system. It considers all the possibilities of heat recovery and the use of excess heat in order to be certain that no supplementary heat is introduced to the process where recovered or excess heat is available as an already existing energy source.

The TSA proposes improved heat integration by connecting the companies within the cluster in a complex system of different pipes for hot water, steam and excess internal fuels. The proposed heat integration system by Hackl et al. (2010) involves a set of different sub-systems. Each sub-system handles the following kinds of excess heat; heated water; high- and low pressure steam and gas. An important aspect is that all the components of the proposed heat distribution network are vital and must be installed as a package in order to obtain the desired results. Hence, companies will use and benefit from heat exchangers and pipelines installed even if these sub-networks are not directly connected with their plant. The different sub-systems can be installed separately but it will lead to lower energy efficiency due to less heat integration. The TSA's proposal requires the involvement of all the companies within the cluster.

Three different levels of heat integration systems were proposed by Hackl et al. (2010) but the moderate alternative is the most realistic and cost-effective network. This version requires moderate changes to the plant areas, which needs to be altered in order to fit the new heat exchangers and pipelines. The moderate changes is ruled to be relatively easy to implement and are the most efficient ones when also considering installation costs relative to potential heat savings (Hackl et al. 2011).

Jönsson et al. (2012) presents an explorative case study of nine different technology pathways for transforming the chemical cluster in Stenungsund to an efficient bio refinery and realizing *"Sustainable Chemistry 2030".* Further, they conclude that a large amount of heat can be saved if the companies succeed to cooperate. According to Jönsson et al. (2012) this kind of heat integration has not been implemented before and if the companies succeed with the collaboration, the cluster in Stenungsund could become a role model for other chemical clusters.

1.2 Problem discussion

The vision of *Sustainable Chemistry 2030* could be important for the cluster to improve in an economic, social and environmental perspective and thus creating a competitive advantage in the world. A first step could be to integrate the heat systems for hot water, steam and internal fuels and thereby achieving enhanced energy efficiency. Two main costs exist in petrochemical production; labor and feedstock/energy. With improved heat integration the energy costs could be significantly lowered and thereby increasing the cluster's competiveness. Hence, the system has a lot of potential both in an economical and environmental perspective.

Previous research shows that it is complicated for the cluster to form a decision, regarding the question about the increased heat integration and at the moment the project has reached a standstill (Jönsson et al. 2012). Further, one of the main issues concerns the collaboration between the companies. Olsson (2011) claims that an allocation of costs could create the possibility to identify and evaluate economic advantages and thereby create a foundation for decisions. However, the solution suggested in the TSA requires that the companies in the cluster collaborate over their own borders and it will lead to a complicated allocation of costs. Another problem is that the companies involved can be described as risk averse, which means that they strive to avoid and minimize risks. Therefore, it is a major problem with collaborating within the cluster since it could lead to a higher degree of risk compared to if the companies' implements internal systems for enhanced energy efficiency instead. Risks and uncertain outcomes also create reliability problems in the cost allocation model, and this is thus an important aspect to consider.

The cost allocation connected with the increase heat integration is complicated due to many factors. First, selling excess heat is not the companies' core business. Further, one important aspect with this investment is not to earn money but to lower the overall costs and emissions. The energy in the potential heat integration system will consist of excess heat. Today it is released directly in the air and heat production is thus not a main product of the production process. Second, the cost allocation has to be divided within the five companies and investments and revenues do not occur within the same company. If a common heat integration system is installed the pricing of the excessive heat has to be determined between the companies in the cluster which raises the question on what principle the pricing can be based on. The cost allocation becomes complicated because investment costs and benefits do not occur on the same place. Hence, if company A invests in heat exchangers and pipes, it would benefit company B, which can use the waste heat and cut fossil fuel costs. Further, the investment cost and benefits are not proportional, companies that have to invest a lot of money might not save that much trough the investment and vice versa.

Subsequently, a cost allocation model will identify how the companies are directly influencing the costs incurred from the system. Further, the information gathered will be necessary to correctly price the waste heat supplied and consumed within the system.

1.3 Question of Research

Based on the problem discussion the following questions of research were formed:

- *What uncertainties and risks connected with the increased heat integration can be determined and how can the risks connected with the project be decreased?*
- *How can a suitable cost allocation model for the increased heat integration distribute the expected costs and savings; and what are the advantages with the selected model compared to the alternatives?*

1.4 Aim

The aim of this bachelor thesis is to evaluate the increased heat integration within the Chemical cluster in Stenungsund regarding the risk- and cost-aspects based on the research questions.

1.5 Delimitations

The implementation of heat integration is a challenging task for the companies within the chemical cluster in Stenungsund. The task is complicated due to several factors and has currently reached a point where the question is not actively driven by any of the parties involved. In the context of this bachelor thesis it is unlikely to find a solution for the collaboration to make a concrete decision due to the fact that it is to complex. Cooperation outside the boundaries of the firm increases their risks and a cost allocation could provide a basis for further discussion.

1.6 Outline

Chapter 1, Introduction, starts with a background description, continues with a problem discussion and leads finally to the aim of this case study.

Chapter 2, Method, explains and motivates the authors´ choice of method. It also contains information about method selections and how they were made in order to fulfill the aim of the paper. Further, it explains how and why empirical material was collected. The method chapter ends with an explanation of analytical methods used in order to analyze the empirical material and an evaluation of this thesis reliability and validity.

Chapter 3, Empirical framework, presents theories that are necessary when analyzing the empirical results.

Chapter 4, Results, presents the results from the interviews and summarizes the cost estimated connected with the increased heat integration in an objective manner.

Chapter 5, Analysis, connects the empirical framework presented in Chapter 3 with the empirical findings in Chapter 4.

Chapter 6, Conclusion, presents the conclusions from this study and suggestions for further work.

2. Method

This chapter presents the design of the case study and how the study has been conducted. Further, it evaluates the reliability of the chosen research design.

2.1 Method of research

2.1.1 Choice of method

Our thesis has been designed as a case study. According to Yin (2009) it is suitable since the aim involves a how question and also proposes to investigate a question in depth rather than one in general. Consequently, a case study is a superior choice of method compared to other methods. The question of research involves a model for cost allocation and identifies uncertainties for the heat integration within the cluster. When the research questions are set, a literature study of different methods could take place and a choice of method was developed. The choice of method should depend of the question of research. If the question seeks answer of how a phenomenon works a case study is relevant. Yin (2009) also claims that case studies are relevant if the question requires an in-depth description of a social occurrence in a contemporary set of events, over which the investigator have no or little control over.

2.1.2 Deductive case study

The aim creates natural settings for a deductive approach which implicates that the empirical results are built on theories Yin (2009). There are three different designs for a case study: deductive, inductive and ethnographic studies. The take-off from a deductive case study can be described as; starting with a formulation of an initiate question with a benchmark from a theory. A theoretical framework is then created, followed by determining the case and a collection of empirical material. Further, the empirical material is analyzed with the theory as a base. This provides a ground for the conclusions. Hence, our case study is performed in a deductive take-off and the working process is performed in line with what Yin (2009) suggests.

2.1.3 Selection of case

A certain case should only be chosen if there is access to both available data and the most suitable candidates that can answer the research questions. Our case was chosen due to the fact that all information was available since the companies involved had agreed to cooperate with Gothenburg Business School with a three year research project. The authors do also have a genuine interest with the companies involved and their work with sustainability.

2.1.4 Mixed methods

A case study´s unique strength is its ability to deal with a wide range of evidences (Yin, 2009). According to Bryman (2003) it is common in case studies to use a combination of quantitative and qualitative data. When both qualitative and quantitative data is used it is referred to as mixed methods research. In order to identify uncertainties a combination of different qualitative methods are used to achieve a wider and deeper understanding of the subject. In order to create a model for cost allocation a combination of qualitative and quantitative data sources were used.

2.1.5 Method´s used in previous research

As already mentioned, the authors could not identify any earlier reports which have a similar purpose as our case study. However, there have been other case studies about the Chemical cluster but with different aims and purposes.

2.2 The implementation of research

This section describes how the case study was performed with focus on the preparation of the case study and continues to describe the collection of empirical material. Further, it also explains how the empirical material analyzed through a combination of results and theory. Finally, it ends with criticisms to the source and an evaluation of the thesis.

2.2.1 Pre-study

This section presents the background of the pre-study, describes how it was performed and its purpose.

2.2.1.1 Interviews

A meeting was arranged with Johanna Jönsson, an independent researcher at SP Technical Research Institute of Sweden, who has been partly involved from the start of the TSA. Jönsson described her perspective of the situation regarding the implementation of a common system and provided us with previous work connected with the project.

The second part of the pre-study was an interview with Eva Andersson who is a research engineer at CIT Industriell Energi AB and one of the writers of the TSA reports. As earlier described, those reports are used as a benchmark for this report. The interview provided the authors with Chalmers perspective on the technical solution and numbers to base our model for cost calculation on.

2.2.1.2 Literature study

Before collecting the empirical material a comprehensive literature study was performed. The first chapter consists of material in the TSA reports and information from the pre-study but also arguments found in books and articles. The theory chapter is mainly based on different books and articles. The reports and books were found through searches in different databases; Gothenburg University (GUNDA) and Chalmers University of Technology (CHANS). Following words were used in order to find fitting material: Cost allocation, Cost management, Risk, Risk management, District Heating, Heat Integration and Sustainability.

2.2.2 Collection of Empirical material

This section describes the selection and gathering of primary and secondary data.

2.2.2.1 Primary data

The primary data was collected through interviews with relevant people representing the companies within the cluster, hereafter referred to as the representatives. The purpose with the interviews was to retrieve information that is necessary to find a suitable cost allocation model and identify uncertainties connected with the project.

The interviews were conducted in a semi-constructed way, where the core in the interview was from a prepared inquiry sheet (see Appendix 1) and spontaneous follow-up questions were also asked during the interview. The first part of the inquiry sheet consists of open question and provides qualitative information which is necessary in order to determine uncertainties. The second part consists of direct question and provides quantitative information which is necessary for the cost calculation.

The criteria for the interviews where that it should be a representative for each company involved. The representative should have a position to make decisions and should also be familiar with the project. The persons who were interviewed are:

- Reine Spetz, Energy Specialist, Borealis
- Göran Lindqvist, Business Development Manager, AkzoNobel Surface Chemistry AB
- Lars Lind, Managing Director, Perstorp BioProducts AB
- Lars Josefsson, Chairman of the Board, Ineos
- Magnus Fransson, Manufacturing Director, AkzoNobel Functional Chemicals AB

AGA did not have any representative who fulfilled the criteria and thereby no interview was performed with a representative from this company. The approach for the interviews contained a short introduction where the writers explained the set-up and each interview lasted about an hour.

2.2.2.2 Secondary data

The secondary data consists of literature study, Chalmers reports and cost estimations provided by Eva Andersson, CIT Industriell Energi AB.

2.2.3 Analytical Technique

This section describes the analytical techniques used in the empirical analysis. It starts general with pattern matching, continues with a description of a SWOT-analysis and ends with a sensitivity analysis.

2.2.3.1 Pattern Matching

According to Yin is one of the most desired analysis techniques is pattern-matching logic. In a logical take-off, pattern matching is a natural choice since it provides the logic to compare an empirically based pattern with a predicted one. In order to define uncertainty we used theory of SWOT-analysis which is further described in Chapter 3 but also briefly below. The empirical results from the interviews with the representatives (presented in Chapter 4) are analyzed and built upon a SWOT-model.

2.2.3.2 SWOT-analysis

A SWOT-analysis consists of a firm's strengths, weaknesses, opportunities and threats. Strengths and weaknesses account the firm's internal capabilities. The external state comprises of opportunities and threats, such as new technology, government regulations and macro-economic developments (Reilly et al. 2002). Conducting a SWOT-analysis for the cluster would enable one to evaluate the improved heat integration and its potential consequences.

2.2.3.3 Sensitivity analysis

Risks and uncertainties connected with the calculation determined by the SWOT-analysis could be analyzed with sensitivity analysis. The purpose with a sensitivity analysis is to determine how the calculation reacts on changes in the different assumptions the calculation is based on (Norelid, 2005).

In sensitivity analysis one variable is changed while the other ones are held constant in order to investigate what happens with the outcome of the calculation (Ross, et al., 2010). This is done by defining the central parts in the calculation and determines the reasonable level of the reliability of the outcome.

The cost calculations and sensitivity analysis are also built upon existing's theories (presented in Chapter 4) and adapted to the numbers in this case study.

2.3 Judging the quality of the research design

This section aims to evaluate the research design and also summarize the authors own evaluation of this thesis. Yin (2009) suggests three ways to judge the research design: construction validity, external validity and reliability.

2.3.1 Construction Validity

The analysis is based on multiple sources of data, from interviews and the TSA reports. By using a combined set of data one could, increase the construction validity of the conclusion (Yin 2009). Further, the TSA reports are according to Hackl et al. (2010 and 2011), based on physical data and the cost is estimated based on Chalmers University of Technology standards. During the interviews, it became obvious that the majority of the representatives doubted the validity of the numbers from the TSA, and thereby also the validity of the cost calculations. However, the conclusion where a model for cost allocation is suggested would still be relevant even if the numbers would change.

2.3.2 External Validity

According to Bryman (2003), one common criticism against case studies is that the results are not generalizable. It might be difficult to expect that the identified uncertainties, cost allocation model and sensitivity analysis could be completely generalized or replicated for another chemical cluster. However, Jönsson et al. (2011) state that the cluster in Stenungsund, is not the only chemical cluster to investigate the possibilities to cooperate outside the borders, in order to increase heat integration. Hence, the defined uncertainties and the discussion about the cost allocation models could be generalized in this sense.

2.3.3 Reliability

We kept protocol and summarized the work of everyday which increases the reliability of the research, since it provides material to use if the study is performed once more. Interviews where taped and as mentioned, the quantitative data mainly consisted of reports which is already published and available for public interests which also provides an increased reliability.

2.3.4 Evaluation of the thesis

Based on the information in the preliminary study, the starting point was originally to evaluate a model for cost allocation. We had the impression that there were no doubts of the system's technical solution and the major problem was for the companies to reach a concrete decision regarding the increased heat integration. In this case, it would be optimal with a purpose to create a model for cost allocation. However, during the collection of empirical material, it became obvious for us that we had chosen a purpose which did not coincide with the state of the project. Therefore, we decided to modify the purpose and add a risk analysis in order to highlight other interesting perspectives. With a relatively small change in the problem description, the purpose could be changed and the relevance of the study increased. However, if we had the chance to write the thesis from start again, we would probably choose another initial approach. It should be noted that, one cannot expect to find a solution for the cluster's standstill in this issue of increased heat integration collaboration with the limited amount of time we had for this thesis.

3. Study Framework

This section covers the chosen theories suitable for the case study. Our first research question is about the uncertainties connected with the project, so it starts with a description of how the risk management process and ends with a further description of the SWOT-analysis and how it is used in this report. Another important aspect is the sustainability aspect and that is also where Hart and Milstein's (2003) model for creating sustainable value comes in. Finally, the different cost allocation models are described in general and are further discussed in Chapter 5.

3.1 Analyze risk and Uncertainty

Risk could be defined as "*internal and external uncertainties, events, or circumstances that the company must understand and manage effectively as it executes its strategies to achieve business objective and create shareholder value*" (Andersen, 2006, p. 31). Risks and Uncertainties are everywhere and institutions are exposed from a variety of them, all from natural catastrophes to uncontrolled human behavior. Calculations contain a range of uncertainty which according to Norelind (2005) are events which makes the outcome of the calculation different from the expected results. Risk management can be seen as a process in order to achieve a projects full potential and gain optimal economic returns, or use to develop a suitable strategy (Andersen & Schröder, 2010). Risks developed during a project are not always something negative. Hence, events connected with uncertainties could be turned into something positive if the risks are actively analyzed and evaluated.

Figure 1. Our illustration of activities included in a risk management process based on Andersson (2006).

Risk management processes can be described as an ongoing process where the activities continue over time. The first step is to identify the different risks that are connected with the project. Once this is done, one can start to analyze the risk and expected outcome with a SWOT-analysis. Based on the assumptions in the risk analysis, an evaluation could be performed with a sensitivity analysis. Finally, the experiences are revised in order to achieve risk modification and adaption of risk activities, so that the firms risk level is acceptable for all the companies involved in the project.

3.2 SWOT analysis

SWOT-analysis is often used in the identification and assessment of strengths, weaknesses, opportunities and threats to yield strategic insights. According to Munier (2011) it is useful to critically examine a project in the decision making process to learn about its strong and weak points. In order to determine risks but also highlighting other important aspects with the increased heat integration a SWOT-analysis can be a useful tool.

3.2.1 Intrinsic factors

The intrinsic factors aim to highlight strength and weaknesses of a project, in this case with the increased heat integration.

3.2.1.1 Strengths

Strengths could be described as the increased heat integrations strong points; presenting what the positive aspects with the project are that creates value for the companies involved. One example of strength could be something new and innovative, or something that have qualities that makes it unique. However, to collaborate within the cluster with a heat integration system is something new, innovative and will make them unique if the companies implement it.

3.2.1.2 Weaknesses

The problem that needs to be addressed and improved with the increased heat integration is referred to as weaknesses. It brings up the weak points of the increased heat integration and tries to explain where it can fail and why. For instance, one weakness with the project is that it could create an increased risk due to collaboration outside the companies own border. Strength and weaknesses are both intrinsic factors.

3.2.2 Extrinsic to the project

3.2.2.1 Opportunities

Opportunities are in this case all the good and worthy things external to the increased heat integration. For example, one important opportunity for the cluster is that they could be more credible as sustainable companies if the increased heat integration system would be implemented.

3.2.2.2 Threats

Threats are defined as all the bad things that can happen to the companies if the heat integration system is implemented, but can also be consequences if it is not. For instance, the technical solution is based on theoretical assumptions and there is always a chance that the solution in reality does not become as good as the theoretical one.

3.3 Creating Sustainable Value

According to Hart and Milstein (2003), a sustainable company contributes to sustainable development by delivering simultaneously economic, social, and environmental benefits. They claims that some managers see sustainability issues as a moral mandate while other see it as a legal requirement. For most firms, the recreation of enterprises sustainability remains difficult to unite with an increase in shareholder value. Hart and Milstein (2003) suggest that sustainable value of the firm could be defined as *"The global challenges associated with sustainability, viewed through the appropriate set of business lenses, can help to identify strategies and practices that contribute to a more sustainable world and, simultaneously, drive the shareholder value."* (Hart & Milstein, 2003, p. 56).

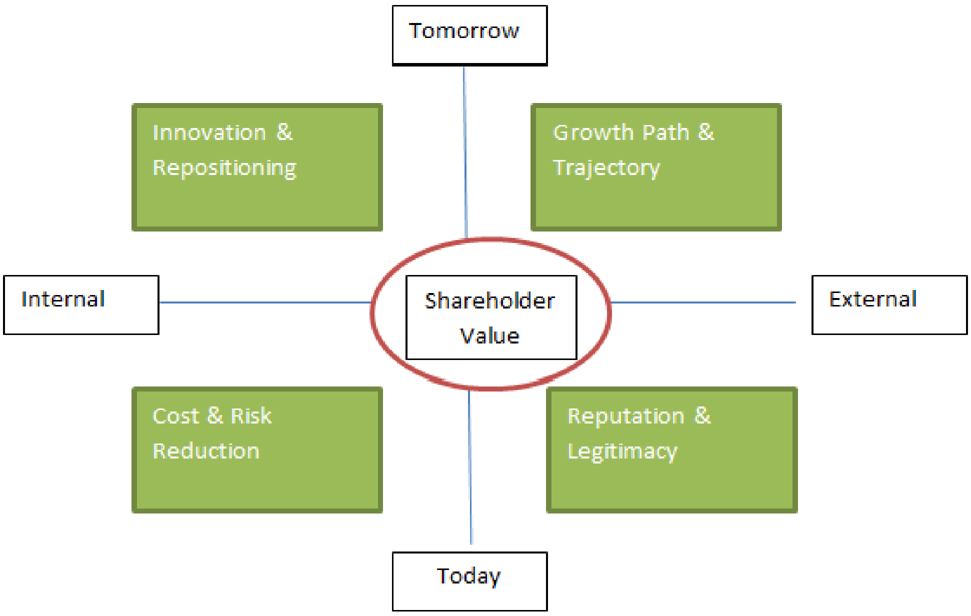

Figure 2. Hart and Milstein (2003) model for how companies can create sustainable value.

The model proposed by Hart and Milstein (2003) is shown in Figure 2. The vertical axis of the model reflects the firm´s need to manage today´s business while simultaneously creating tomorrow's technology markets. It captures the business need to realize short-term profits but also the expectations on long term growth. The Horizontal axis reflects the firm´s need to grow and protect internal organizational skills and capabilities while at the same time filling the firm with new perspectives and knowledge from the outside. This dimension describes the balance between the technical core and fresh perspectives. The lower left quadrant focuses on those aspects of performance that are primarily internal, mainly cost and risk reduction. The lower-right quadrant focuses on performance in near term future and includes relevant stake holders outside the firm. The upper left quadrant corresponds to the balance between being efficient in today's business but also be mindful of generating the products and services of the future. The upper right quadrant focuses on the external dimension associated with future performance. Therefore, the firms must be well performed in all four quadrants of the model in order to maximize shareholder value over time.

3.4 Cost allocation

3.4.1 Common costs

According to Zimmerman (2003) the purpose of cost allocation is to assign indirect, common, or joint costs to different departments, processes, products, or programs. This is essential for corporate leaders to be able to make the best decisions and control their assets and investments. Cost allocation is used for multiple reasons which means that every situation will be different and the allocation of common costs to cost objects do not have one generic model that will always be right or wrong and . The technique of allocating common costs requires trade-offs in choosing whether and how to allocate a given common cost. And the exact methodology for a cost allocation depends on what purposes the allocation serves.

Cost allocation requires the following steps: (Zimmerman, 2003)

1. *Define the cost objects*. The first decision is what departments, products, processes, or programs to cost. Cost objects are often allocated to an organizations subunit in order to better evaluate the subunits performance.
2. *Adding the common costs to the cost objects*. The identification and allocation of common costs, in our case pipelines and heat-exchangers as examples, is needed in the next step. Common costs will then be distributed among its users.
3. *Choose a method for the allocating of common costs accumulated in step 2 to the cost objects in step 1*. An **allocation base** is a measure of activity associated with the group of common costs being assigned to the cost objects. And this allocation base has to be selected, in our case it can be the amount of heat flowing through a certain pipeline or maintenance costs associated with the heat exchangers or some combination. Common costs are usually allocated to cost objects using an allocation base that approximates how the cost objects use the common utilities.

3.4.2 Calculation models

Full costing calculation considers all the corporations costs for a product in the calculation Olsson (2011). The idea is for the product to draw a fair share of the overhead costs that it incurs. The direct costs will however be referred to each calculation object.

Activity based costing is a method in which the discretionary costs of an object are applied based on the different activities that causes these costs according to Hilton (2003). With the activities the costs can then be considered in an object calculation.

Another common calculation method is contribution *margin costing* which only considers the variable costs of an object. These costs is a consequence of a decision and do not include the fixed costs. However, corporation often calculate a contribution margin for their overhead costs. The object must then be able to cover this margin cost that it causes. (Olsson, 2011)

Proponents of ABC calculations believe it presents more reliable estimations and thus providing a better basis for decisions (Drury, 2004). And unlike the other methods, it does not underestimate the profitability of high volume products while overestimating the profitability of low volume products because it only allocates costs depending on the amount of resources a unit consumes. However, our cost allocation calculation from the TSA will not require such a complicated model and further data would have been needed to perform an activity based calculation.

The difficulty with full costing and ABC calculations is the allocation of common costs. A complete objective methodology does not exist and all the alternatives are more or less subjective. A cause related allocation consists of a cost being allocated to the object affecting it. According to Drury (2004) companies allocate costs for comparing profitability, cost-based pricing and decision making. When comparing profits a cost allocation can determine how a division or product is performing, which requires an inclusion of objects indirect costs. Subsequently, showing the true cost for a product or division could help eliminating unprofitable units.

These three allocation methods do not exclude each other. Instead they should be seen as completing each other's shortcomings though a particular aspect is in focus with each method. A full costing calculation will allocate all the costs for the heat integration system amongst the companies within the cluster. It is very important to allocate the common costs that cannot be traced directly to a division though these costs consist of such a large share of the total costs. However, we think a marginal costing can contribute to the cost allocation by giving us a different aspect of how the costs can be allocated. One of these aspects that are important to showcase is that marginal costing can show the profitability of different decisions, products and divisions. Marginal costing is however primarily used for short-term analysis because long-term decisions often have substantial effects on a organization's overall costs.

4. Empirical Findings

This chapter presents the results from the interviews in an objective manner. The chapter aims to only reproduce the interviews and note that this chapter do not involve any of the authors own opinions. Finally, the result of the cost estimation is presented. See Appendix 1 for a summary of the questions asked during the interviews.

4.1 Summary of interviews

4.1.1 Attitudes against the potential of the heat integration

All the involved companies concur that the investment has a large potential, both when it comes to an economical aspect and sustainability. Two of the representatives have even mentioned that it could have the single largest energy saving potential in Sweden. However, all representatives also agree on that they need to put in more engineering hours in order to clarify its true potential and are concerned about the uncertainties connected with it.

One representative claims that “energy efficiency should be one of the ground settings for the future, sooner or later energy efficiency projects needs to come ahead. In order to be profiled as green it is necessary to decrease the energy need”. A number of representatives agreed on that the efficiency have to increase in order to stay competitive.

Some representatives claim that there could be a psychological effect and that the “*common investment can create synergies*” which makes the cluster stronger in the long term. One representative claims that a common investment will make the cluster stronger but that it will not create any value for the company itself. Another benefit which could be created according to one of the representative is the marketing perspective. The increased energy efficiency may not be any argument in order to increase sales for a single product but can be useful when it comes to marketing the whole enterprise’s image.

4.1.2 Obstacles and Risks

The representatives are all concerned about the size of the investment. A large investment is always connected with a high risk. The budgets are limited and the energy efficiency investment also competes with production investment that increases production volume and/or capacity. Those projects normally have priority before energy efficiency investments. Another problem is the pay-back time, all the representatives claim that the companies require a pay-back time of one to two years. However, two representatives argue that they could allow longer pay-back time for energy efficiency investments due to the sustainability approach. Another problem two representatives have raised is the companies’ different financial cycles. An optimal period for initializing an investment of this kind would be when all the companies are showing strong financial results. However, the companies are in wide different financial states at this moment and the timing is thus not the optimal.

According to all the representatives more engineering hours are necessary in order to determine the system's true potential. One representative wants to see a neutral consultant while others claim that it is necessary to provide a better internal study first. However, some of them also claim that it is most necessary to come to a decision before more time and money is spent on the technical solution. Another point of view is that Chalmers has deeply underestimated the complexity of the system. The model needs improvements and a more detailed pre-study is needed. The same representatives also assert that the next step should be to develop an appropriate business model.

All the representatives agree that one key obstacle is the collaboration issue and there are many factors which obstruct collaboration. First, the cluster has a long history of collaboration and memories of earlier failures which makes the situation more complicated. Secondly, the wrong people in the organization might be responsible for the heat integration investment at the moment. Thirdly, the companies are all affiliates and the CEO´s in Stenungsund are small players in large multinational companies which aggravates the decision making process within the organizations. Fourth, the role of management is not set when five independent companies are to collaborate, there is no natural leader, and thereby no one to drive the question or take lead. Fifth, all representatives are basically loyal to their company, will see to its own best and try to benefit on the expense of the other companies.

There are several risks connected with the technical solution of the common system. The complexity will increase due to inter connection of all systems and result in increased risk. The heat integration allows production problems to propagate. Hence, if one site within the cluster has production problems, it could affect the other site's production processes. The heat integration system also removes part of the total control they have over their production process which have been expressed as being a considerable inconvenience. There are also practical risks like the quality of steam and hot water which can create corrosion and material problems. Further, the risk connected to one company deciding to terminate its activities in Stenungsund lingers to which it will significantly impact the other companies. However, the opinion about the system's complexity varies between the representatives. Some of them share Chalmers (Hackl et al. 2009) view of it as a relatively simple technical solution while others sees it as a very complicated process.

4.1.3 Cost allocation

The companies have several previous bi-lateral investments and are used to collaborate over the company borders when it comes to smaller investments where risks are lower. The opinion about how costs and profit should be divided varies between the companies. An opinion is that the costs for the investment should first be divided into part projects and the investment should be bilateral. One solution could be to create an external company where all companies´ are equal shareholders but this solution would be difficult. One of the representatives also claim that this complicated question is all about collaboration; *"it is important to think beyond the company borders and do what's best for the cluster in general".*

Another possible solution suggested by several representatives is to bring in an external part to carry the investment and who buys the energy from the cluster and then sell it further to a higher price. In this case it is easier to see *"what is in it for me and what is in it for you".* It could also work if one of the involved companies decides to take the lead if it has the possibility but this is not likely. Consequently it is better if an external company which has energy as its core business, like one of the large municipal companies, to take over "Sweden's largest energy saving investment". This should be done in connection to a long term agreement in order to create a level of certainty.

All the representatives involved agree on that the price of excess heat should be connected to the market prices. The way to estimate calculation rate varies significant between the companies and so does also the depreciation time which was estimated between 10 and 25 years.

4.2 Cost Estimations

Table 1 demonstrates the ratio of cost and benefits between the companies, due to the increased heat integration. The ratios in table 1 are derived from values calculated by Eva Andersson, and are an improved estimation compared to the one presented in the TSA reports.

4.2.1 Summarization of the estimation of cost and benefits for the whole cluster

Table 1 displays the ratio of cost and benefits between the companies. AGA do not gain any benefits from the investment but they have to carry cost corresponding to 1.5% of the total investment. AkzoNobel would gain 8% of the total savings and they only have to carry 4% of the costs. With costs of 56% has Borealis the largest amount of costs connected with its site and they will only gain 7% of the total savings. Ineos carries 11% of the total investment and they earn 20% of the total savings. Perstorp will have the largest fuel cost saving benefits corresponding to 66% but they have to carry 27% of the total costs. Consequently, the costs and benefits varies widespread between the companies and some of them gain more than they have to invest and vice versa. The winners are AkzoNobel, Ineos and Perstorp while AGA and Borealis are the companies with the smallest benefit from the investment.

Table 1. The total cost ratio and savings ratio of each companies.

	AGA (%)	AkzoNobel (%)	Borealis (%)	Ineos (%)	Perstorp (%)
Ratio of total cost	1,5	4	56	11	27
Ratio of total savings	0	8	7	20	66

4.2.2 Cost estimation between Borealis and Perstorp

As shown in Table 1, the companies which have the most impact on the heat integration are Borealis and Perstorp. Therefore, the authors asked Eva Andersson what the results would be if the heat integration where only performed between Borealis and Perstorp. We saw that the amount of energy saved would decrease to 73% and the expected cost would be reduced to 81% in comparison heat integration is performed in the whole cluster. Subsequently, one still save a lot of energy if the heat integration is performed bi-lateral between Borealis and Perstorp. This option will also be further discussed in the following chapter.

4.3 Summary of Empirical Findings

This section summarizes our interviews. The involved companies concur that the investment has a significant positive potential, regarding both the economical and sustainability aspects. However, all representatives also agree that there are many risks connected with the technical solution of the heat integration and with collaborating within the cluster. The results from the interviews will be analyzed further in the following chapter.

The ratio of cost and benefits are unequal between the companies and there are distinctive winners and losers. While it was important for the representatives that the cost allocation for this investment would be fair and equal, they also realized that it would not be perfect. However, the analysis chapter will further discuss the allocations of cost and benefits.

5. Analysis

In the following section the heat integration for the enhanced energy efficiency project is evaluated through a deductive analysis. It starts with analyzing the results from the interviews based on the SWOT-analysis. The analysis suggests and evaluates different models for cost allocation and also includes a scenario analysis based upon the assumptions discovered in the SWOT-analysis.

5.1 SWOT-analysis

According to the theory, risk management starts with the identification of important factors which affect the economic assets and business activities. According to Norelind (2005), an uncertainty does not necessarily lead to a risk. In order to analyze the uncertainties connected with the heat integration the results are analyzed using a SWOT-analysis. In the SWOT-analysis the internal strength and weaknesses of the heat integration are determined as are the external threats and opportunities. The internal analysis has the TSA as benchmark, with strengths and weaknesses for the companies being determined.

In order to justify some of the arguments as strengths and opportunities, we have used Hart and Milstein (2003) model for creating sustainable value. For weaknesses and threats, explanations have been given for how those could be improved or prevented. This chapter ends with a summarization of the SWOT-analysis and suggestions of how the costs could be allocated in order to avoid weaknesses and threats.

5.1.1 Strengths

According to Hackl et al. (2011) the cluster could save up to 90 MW in fossil fuel usage and all the representatives agree that the heat integration system holds a tremendous energy savings potential. A number of the representatives have even described it as having *"Sweden's single largest energy savings potential".*

According to Hart and Milstein (2003), the creation of shareholder value requires the performance in multiple dimensions involving economic, social and environmental concerns. As previously mentioned in the introduction, pollutions can be seen as a sign of costly and inefficient production (Schaltegger, et al., 2008) and at the moment the cluster is a major emitter of carbon dioxide. However, with the heat integration system the cluster could decreases its pollution and fuel costs. In the TSA, the cost savings for the cluster is estimated to roughly SEK 180 million a year. Hart and Milstein (2003) claim that by minimizing waste and emission from the daily operations the payoff could be described as cost and risk reduction and thereby the companies could be one step closer to becoming more sustainable enterprises.

If the companies succeed to collaborate around this particular question it could also create a foundation and trust for further collaboration in large and complicated questions. In order for the companies to fulfill their common sustainability vision, energy efficiency should be one part of it.

All the representatives from the companies agreed that heat integration is needed to realize the vision of "Sustainable Chemistry 2030". One important aspect that should be noted is that by only formulating a common sustainability vision the cluster has made these international companies unique in the world.

5.1.2 Weaknesses

One weakness is a lack of credibility of the TSA, even though this varies between the representatives. The common opinion about the TSAs credibility is that more engineering hours are required in order to determine its true potential. The TSA could according to one of the representatives be optimized and he claims that the TSAs estimated amount of energy that could be saved is too optimistic. It seems also like the representatives of the companies expect the other representatives to share their opinion. This was confirmed several times during the interviews. For example, when they were discussing depreciation time for the utilities they said that it should be a certain amount of years and when asked to motivate their answers they gave their explanation and said *"it should be seen this way and I think that everybody else shares my opinion".* However, this was not the case. There is a chance that the wrong decision is made because the parties involved do not communicate enough with each other. One of the representatives also claims that it is not the right person who is responsible for this particular question. Arranged meetings on regular basis could therefore create a stronger basis for trusting each other because increased collaboration was mentioned as a key issue in implementing the heat integration system. One problem is the lack of goals and deadlines and it is also confirmed by one of the representatives who also added that this kind of projects do not have an "best before date". This problem is also likely connected with the lack of natural management which occurs when different companies collaborates since there is no natural leader. Another problem is the decision process within the companies because the final decision has to be made outside of Stenungsund. Subsequently, the potential implementation of the integration system would be at a further stage if the companies shared the same views about the project.

The technical solution is according to the representatives connected with several risks since the heat integration will create a more complex production system. One risk connected with running the system is that if a problem arises at one site it will be transferred to another and so on. Another risk with the heat integration, acknowledged by the representatives, is if one site decides to change or quit its production in Stenungsund. In order to decrease those risks and the complexity one could think of a bi-lateral integration between Borealis and Perstorp. This scenario would still save 73% of the full heat integration implementation. Another solution suggested by several of the representatives in order to decrease the capital risk is to bring in a third party which has energy as its core business and would carry the investment. The third party could buy energy from the companies cheap and sell it back to the companies on a long term agreement. In this case there would still be technical risks due to the system complexity but it would minimize the economic risk. This solution would also ease the cost allocation and question of ownership.

The total costs of this investment are seen as a weakness. First, the representatives have mentioned their demand on a pay-back time as one to two years which cannot be encountered for the heat integration. Second, huge investments are always connected with a large risk since there is always a chance to lose a lot of money. Third, the cost allocation and ownership becomes rather complicated. Fourth, the companies have to follow the same financial cycle and be able to invest at the same time which is a process that becomes complicated with five different companies involved. However, all those problems could be eased or avoided with an external company. The cost allocation and ownership question could also be significant eased if only two of the companies were involved. If the heat integration is performed between Borealis and Perstorp it would also ease the collaboration issue since they are used to collaborate in bi-lateral investments.

5.1.3 Opportunities

Heart and Milstein (2003) have created a sustainable value framework which links the challenges of global sustainability to create shareholder value for the firm. Their model describes an external growth trajectory and one for reputation and legitimacy. The cluster has decided to adopt a common vision which is called *"Sustainable Chemistry 2030".* One of the representatives told a story about a presentation of the vision which he held for some inhabitances in Stenungsund. He had limited time and needed to leave out parts of his presentation and subsequently left out the increased heat integration. Although the first question asked by the audience were "*but do you do anything in order to be more energy efficient?*". Hence, the energy efficiency project is important in order to create credibility, noble reputation and legitimacy. Those are also factors which according to Heart and Milstein (2003) are important in becoming a sustainable enterprise. The carbon footprint will be decreased in case the companies decide to implement the heat integration. According to one of the representatives the decreased carbon dioxide emission could be used in a marketing perspective, not only in marketing a one single product but the companies' whole images.

Some of the representatives have mentioned the synergies which the heat integration generates in case it is implemented. The implementation of the common network will be likely to increase the efficiency of the company since it provides a lower use of external fuel. If the efficiency is increased it might help the companies to be more competitive in the long term. Higher efficiency might generate an opportunity for the individual companies in the cluster to be stronger against the threat of closure due to cost savings. If the heat integration is performed the cluster will also stand stronger against possible future fluctuation in fuel prices. Hart and Milstein (2003) claim that a sustainable vision should create a shared roadmap for meeting future needs. With a development of increased competition and higher awareness among the customers the heat integration might fulfill unmet needs. It might also create the possibility to face possible future stricter environmental regulations.

5.1.4 Threats

Threats are present against the cluster whether the heat integration is implemented or not. In this section both scenarios are discussed.

One could claim that it is a threat if the investment is not performed. In case the fuel price increases significantly and if the companies are not energy efficient this scenario will have a very large impact on the cluster.

As some of the representatives claimed during the interviews, all energy efficiency projects are not certainly good. As one of them mentions, one possible risk connected with the heat integration is *"if the solution is to complex the harm will be larger than the benefit"*. Subsequently, if something goes wrong with the project there is a chance that the cluster becomes a warning example of how energy efficiency across enterprise boundaries could look like and thereby have a negative influence over future projects. This risk will always be present but with better evaluations by engineers and better calculations it can be decreased.

If one of the parent companies decides to close its establishment in Stenungsund, it would have a negative impact on the overall heat integration system. Another possible threat could be that the investment is far away from the enterprises' core business. Hence, precious time and resources could be taken from increasing the production efficiency. However, those two threats could easily be avoided if a third part could go in and carry the entire investment.

5.1.5 Summary of the SWOT-analysis

According to Hart and Milstein (2003) can the global challenges associated with sustainability help to identify strategies and practices that contribute to a sustainable world and simultaneously increase shareholder value. They have developed a *sustainable-value framework* that links the challenges of sustainability to create and increase shareholder value for the firm. One could claim that if the heat integration is implemented, it could strengthen all parts of Hart and Milstein's (2003) model and thus increase the cluster's sustainable value.

From the SWOT-analysis it is also evident that the increased heat integration is connected with many risks and uncertainties. However, it is rather obvious that a lot of weaknesses and threats could be avoided or eased by; having an external third party operating the system or if the heat integration is only performed between two of the companies.

5.2 Cost Calculations

5.2.1 Assumptions

The following assumptions were made for the calculations. The calculations for the expected revenues and costs for pipes, heat exchangers and maintenance were made by Hackl et al. (2009) and have since been recently revised. Utilities that require large initial costs have progressive depreciations because the bulk of the total costs are paid for the first year (Drury, 2004). Finally, the economic life and cost of capital were an average estimation from our interviews with the representatives. Heat exchanger costs include material costs, cost for installation, changes in maps etc.

5.2.2 Full costing calculation

Table 2. Our full costing calculation for installing the heat-exchange system within the cluster.

(MSEK)	AGA	Akzo	Borealis	Ineos	Perstorp	Total
Savings	0	14	13	35	118	180
Direct costs, VVX	-1,7	-5,3	-116,2	-31,8	-37,7	-192,8
-Amount of MW recieved	0	6,8	-6,5	17,4	-58,5	89,2
-Share of common costs*	0	-34,8	-33,3	-89,1	-299,5	-456,6
% of common costs absorbed	0%	7,6%	7,3%	19,5%	65,6%	100%
Maintenace costs**	0	-0,14	-0,13	-0,35	-1,17	-1,78
Depreciation***	0	0	-1	-1	-3	-6,5
RRR****	-0,2	-4,8	-17,9	-14,5	-40,5	-77,9
Sum	-2,0	-32	-156	-102	-264	-555,8
	*Pipelining costs based on MW of energy received **2 % of VVX costs ***1 % the first year ****Required rate of return 12 %					

Our full costing calculation is based on revised numbers derived from the previous work of Hackl et al. (2010) and can be seen in Table 2. The heat exchanger costs can be directly traced back to each company. We see that Borealis carries SEK 116 million or 60% of the total amount of heat exchangers needed for the entire system due to the company being the main supplier of excess heat. Contrary to contribution margin allocations, full costing method requires the allocation of all common costs (Drury, 2004). The representatives agreed that the common costs should be allocated fairly and required that each company should benefit from the system. This means that the companies that have to invest in large amounts of heat exchanger and act as excess heat suppliers should be compensated for the energy they deliver. A market mechanism was accepted for the price setting; however the price should be lower than the market price but high enough for expecting a reasonable payback time for the incurred heat exchanger costs.

A generally accepted approach would be to allocate the common costs based on utilization, which would be a cost allocation base that considers the amount MW of energy each company will receive from the heat integration system. Perstorp being the main receiver of excess heat and thus the one who can cut fossil fuel costs the most will therefore carry almost SEK 300 million or 65% of the total common costs.

Direct costs can be directly referred to objects causing the costs (Zimmerman, 2009). Costs associated with the heat exchangers can be traced back to each company and can therefore be seen as direct costs. It can be argued that an installment of a heat exchanger on site A will benefit site B and site B should then be obliged to bear the expense. However, the requirement for heat exchangers indicates having a role as a heat supplier. And heat supplier will be compensated for the excess heat they supply within the cluster.

One important aspect is that these calculations are an overall allocation for only the first year of the investments lifecycle. The following years will bear approximately the same amount of fuel savings, which are approximately SEK 180 million per year depending on current market prices, but the large initial installation and equipment costs for the first year will be gone. Therefore, it may not be fair to the heat integration system to only consider the first year. However, the calculations could show the strong economic advantages of implementing the system, even only considering the first year. Further, the energy pricing by Chalmers can be discussed. During our interviews an average market price of 300 SEK/MWh for electricity, steam and hot water was accepted by several representatives. However, Chalmers price setting is 200 SEK/MWh, a substantial underpricing of the energy and it is an important consideration when analyzing the calculations. It should also be noted that the energy can be of different quality and depending on pressure and temperature, variances in pricing will occur. Further, this variation in energy quality was expressed as another risk factor by the representatives.

The full costing method gives the heat integration system a fair cost allocation. Because the amount of saved energy is a suitable allocation base in this case, and it is also confirmed by the representatives. Therefore, with this model Perstorp is carrying a larger portion of the indirect costs of piping due to its high energy savings. For the full costing method; Perstorp, Ineos and AkzoNobel show a reasonable payback time of 2-3 years. The payback time is slightly higher than for an ordinary investment, but this is an energy saving investment and all the representatives has indicated that a longer payback time could be accepted for energy efficiency investments.

5.2.3 Contribution margin calculation

Table 3. Our contribution margin calculation for installing the heat-exchange systen within the cluster.

(MSEK)	AGA		Akzo		Borealis		Ineos		Perstorp		Total	
		%		%		%		%		%		%
Savings		100	14	100	13	100	35	100	118	100	180	100
Costs, VVX	-1,7		-5,3		-116,2		-31,8		-37,7		-192,8	
CB1	-1,7	0	8,7	63,5	-103,2	-788	3,2	9	80,3	68	-13,0	-7
Maintenance costs*	0,03		0,11		2,32		0,64		0,75		4	
Depreciation**	0,02		0,05		1,16		0,32		0,38		2	
RRR***	0,21		0,64		13,9		3,82		4,53		23	
Sum	-0,26	0	-0,80	4,67	-17,4	106	-4,77	11	-5,7	3,8	-29	13
CB2	-2,0	0	7,9	57,6	-121	-894	-1,6	1,8	75	63	-42	-20
	*2% of the total heat int. system costs								**Common costs**			
	**1% progressive depreciation the initial year								Pipes		457	
	***12% required rate of return								Depreciation**		4,6	
									RRR***		55	
									Sum		-516	
									CB3		-558	-310

The direct costs consist of heat exchangers needed on each site and can be seen in our contribution margin calculation on Table 3. AkzoNobel's and Perstorp's first contribution margins are disproportionally high and carry most of the fuel savings. Further, Borealis is on the other side of the spectrum where they have the largest traceable costs of SEK 116 million matched with the lowest fuel savings, SEK 13 million per year. AGA can be dismissed from taking part of the project due to the negligible effect in terms of fuel savings and investment stake. The major supplier of excess heat in the heat integration system is Borealis which means that they will absorb a significant part of the savings in form of revenues from selling their steam and hot water. The profits from the fuel cost savings made by Perstorp and Ineos will therefore accrue Borealis to a certain extend due to Borealis being the main supplier of excess heat. Consequently, a portion of AkzoNobel's and Perstorp's savings are actually Borealis revenues and the size of these revenues depends on Borealis price setting for selling their excess heat. The pricing will determine how large the share of the total fuel cost savings Borealis takes in possession. A price mechanism accepted by the representatives is to connect the waste heat pricing to the market.

Another aspect with contribution calculation is that the profitability of the different sites can be compared with each other regardless of size. However, the overall savings and investment stakes should be taken into account if considering a participation in the heat integration system and the minimal impact from the participation of AGA and AkzoNobel is thus a cost-benefit issue.

The site with the highest contribution margin, in our case Perstorp with 80 and 75 %, is usually the most effective and profitable one. However, a high contribution margin could be misleading if a site is causing the major shares of the common costs but this important aspect of this investment cannot be seen in a contribution calculation because the common costs are not allocated. Another important aspect is that the share of the common costs, SEK 516 million, is a substantial part of the total costs of this particular investment. And having this amount of common costs not allocated would only bring more ambiguity to the project.

5.2.4 Activity based Calculation

An activity based calculation would have proved itself too complicated and time consuming for this case. ABC is intended to examine complicated production processes and this investment has only one activity which is quite simple and this activity receiving excess heat have been the cost allocation in the full costing model.

5.2.5 Sensitivity analysis

The Chalmers report has based their calculations on an average energy price of 200 SEK/MWh. It would therefore be interesting to see the how well the investment would do in terms of a possible payback time if we would alter the energy price parameter.

Table 4 The first sensitivity-analysis based on the average price for electricity, hot water and steam.

Entire Cluster	Price		
	SEK 1 m/MW	SEK 2 m/MW	SEK 3 m/MW
Cost Savings	90	180	270
Total inv. Costs	649	649	649
Payback time	7,2 years	3,6 years	2,4 years

An energy price of 100 SEK/MWh would drastically increase the payback time to a level which would probably be seen as unacceptable for this project. The likeliness of decreasing energy prices can however be questioned. A more suitable price is 300 SEK/MWh according to the company representatives which considered it as the current market price. With this change, the payback time would be just short of three years and fits better with the demand of a payback time of two to three years from all but one of the companies. One company had a requirement of all invested funds being repaid within the first year. While the other representatives took into account of this being an energy saving investment and prolonged the required payback time with one to two years.

Table 5 The second sensitivity-analysis for the total costs (pipes and heat exchangers) of the investment.

Entire Cluster	Total investment costs		
	30 % decrease	No difference	30 % increase
Cost Savings	180	180	180
Total inv. Costs	454	649	844
Payback time	2,5 years	3,6 years	4,7 years

The next parameter being analyzed is the cost of the whole investment. The Chalmers calculations already include a 30% total increase for unforeseen costs. With the total costs being increased with additional 30 % we see a prolonged payback time of almost one and a half years. And a decrease in total costs will bring the payback time into a position where this system would be seen as more reasonable and potentially directly realizable.

5.2.6 Borealis – Perstorp cooperation

One suggestion to further along the heat integration investment would be to install the heat integration system between only the two major beneficiaries. Borealis is the main supplier of excess heat and Perstorp is the main recipient. A revised calculation by Chalmers examines this option. One can note similar total cost expenditure needed. An increase in heat exchangers on Borealis site is demanded due to Perstorp high demand of excess heat, which also leads to higher share of common costs. The cost-effectiveness is therefore slightly lower than the full implementation option in terms of payback time, which is seen as a problem and an obstacle by the cluster. During our interviews we could note a concern about the optimization for the entire heat integration system. Several representatives expressed that the whole system could be reduced in size and only focus on the most effective integration aspects. This would mean a lower overall MWh saved and thus fuel cost savings, but substantial reduced investment costs in contrast to Chalmers approach.

5.2.7 Building blocks for a potential contract

In our interviews we have found the following basic building blocks of what the heat integration contract should consist of: (i) a minimum amount of heat that has to be produced/received, (ii) heat pricing and pricing mechanisms, (iii) measuring the heat transported, (iv) ownership of equipment, (v) ensuring the heat supply (vi) starting and ending the contract (vi) cancellation of contract and compensation.

Further, there are three main options for ownership:

1. The companies within the chemical cluster in Stenungsund own the heating network and obtain control over the service.
2. External third party owns and controls the system and the cluster pays only for the heat received.
3. External financier invests the money needed and the customer receives ownership of the heating network after the investor has their invested money back.

A third party owning and maintaining the heat integration system was the option all the parties involved agreed was the most possible to achieve. If this option would become available with an investor who can accept a higher payback time, possibly with a local municipal investor, our belief is that the companies would take part of the heat integration system as customers, signing long term energy contracts and only paying for the heat received.

5.3 Selection of a cost allocation model

The most suitable calculation method is the full costing model. A part from contribution margin calculation, full costing considers common costs as a part of the investment and allocates them with an allocation base, which in our case was one proposed by all the representatives. Further, ABC calculation should not be considered since the intent is not to examine a complicated production process.

6. Conclusions

This report presents a case study about increased heat integration, within a chemical cluster, where uncertainties are determined and a model for cost allocation is proposed. The results have been analyzed, discussed and the following conclusions could be drawn while also contributing with suggestions for further work.

We suggested that a model for cost allocation could create a foundation for decision making in the problem discussion. This does unfortunately not seem realistic at this point and time. At this stage, a concrete decision about how to proceed with the heat integration project should come before the discussion about cost allocations rather than vice versa. Another interesting aspect when it comes to forming a decision is that the companies within the cluster are subsidiaries with headquarters located outside the borders of Sweden. This makes the decision making process longer and more complicated. The decision making within these kinds of ownership structure could therefore be worth studying for future work.

The SWOT-analysis shows that increased energy efficiency provides many opportunities due to the cost savings and sustainability aspect. However, cooperation within the chemical cluster will also increase the risks and threats, which could be avoided or eased, with the involvement of an external party or a bilaterally agreement. These two alternatives ease the collaboration issues and the question of ownership and cost/benefit allocation. It would therefore be interesting to investigate a possible business model for this project. By also analyzing the technical and economic risks connected with the project.

Further, the full costing model proved itself to be the most suitable method because it allocated the common costs incurred from the heat integration system. We used a fair and balanced approach when we allocated the common costs based on an allocation base proposed and accepted by the representatives. The contribution margin model did not consider allocating the common costs while activity based costing would have been too multifaceted for a non-producing and simple process. It was also noted that even if Chalmers proposed a moderate system with consideration to both energy savings and investment costs, the representatives desired a more cost-effective approach.

It was claimed that the main problem with this project was collaboration but this point of view is not shared with us. There is indeed a lot of collaboration issues connected to the heat integration project but we claim that the main problem lies with the heat integration system. The companies do already collaborate and have a long history of common investments but not with one connected to such a substantial risk as this project. If the increased heat integration would have been economically more beneficial for all parties involved, incurred a low risk level and had an easy technical solution, then it is not likely that the collaboration issue would exist. However, the main problem is that the project is too costly, has a high risk, will increase the complexity of the existing production processes and it is not a part of any of the companies' core business. Thereby, the interest from the involved companies' is too small to drive the question further. We think that the only solution, in order to succeed with the increased heat integration system, is to bring in an external part who wants to carry the risk and have the opportunity to be a part of something which could be "*the single largest energy efficiency project in Sweden*". Indeed, one could claim that a third party will experience the same problem but if the potential investor have energy as its core business, it might be more likely that one could accept the higher payback time and higher risk. Another argument could be that energy companies already deal with this kind of problems, for example with district heating, where they buy energy from companies and sell to households. Further, this option provides the opportunity for the cluster to profit in two ways; they avoid the large investment costs but benefit from the creation of sustainable value.

AGA did not have any suitable representative that was willing to participate in an interview. But it will not change the outcome of the cost allocation model. It is evident from the model of cost allocation that AGA does not have any economic benefits connected the heat integration system. However, AGA can still benefit from the sustainability aspect and cooperating within the cluster can make them more competitive on the world stage.

Further, the TSA aimed to optimize the energy efficiency within the cluster. One aspect that we share with the representatives is that the proposed heat integration system in the TSA could have been more cost-effective. It would therefore be interesting to perform a future study where minimizing the investment costs would be of greater importance than opting to increase the total amount of energy saved. Such a system would be more realistic and easier to implement. And would it then be technically and economically successful it could then be expanded.

A previously mentioned viewpoint of the heat integration system is that it is risky because of its initial investment cost, long payback time and unclear technical conditions. However, the potential economic, societal and sustainability benefits from conducting such an investment could probably be larger than its negative aspects in the long term. Implementing the investment would be unique in the world and also create a potential model for other chemical clusters to replicate. Further, the competiveness and credibility of the cluster in Stenungsund would increase with them being on the sustainability forefront.

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Appendix

Appendix 1 shows the inquiry sheet used during the interviews.

What is your role in the company?

What do you think about the improved heat integration system and is a milestone for reaching sustainable chemistry 2030?

What benefits will the heat integration bring apart from the financial aspect?

What are the competing investment projects to the heat integration?

What do you feel is the most difficult obstacles to implementing the system?

What risks can be linked to the system?

Have a common investment been made earlier in the chemicals cluster and how were the common costs allocated?

Is Chalmers TSA-report reliable enough for potentially implementing the investment?

What would be the basis for a possible pricing of excess heat?

Which cash flows do you consider as associated with the project? Do you think the estimation in the TSA is a reasonable?

Is there a link between investment joint costs and pricing of excess heat?

What is the current cost of capital for this type of project?

How should the utilities be deprecated?

What is the required payback time for this kind of investment?