COST-EFFECTIVE ENERGY TRANSITION FROM GAS TO ELECTRICITY AT A METAL PROCESSING COMPANY

PROJECT PLAN FOR A BACHELOR THESIS IN INDUSTRIAL ENGINEERING AND MANAGEMENT

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1 Introduction

This project plan is made to give a general guideline for the upcoming bachelor thesis of Industrial Engineering and Management. It will give insight in the problems and in the approach used to solve these problems. This report will discuss: the problem, the research design, Philosophy of Science and Business Ethics and finally the Feasibility and Personal Development Plan.

1.1 Company Description

Coes Metaalbescherming BV is a company that has over 60 years of experience in blasting and coating metal constructions. In all these years they have treated a wide variety of parts and products like: steel constructions, tanks, trailers, containers, pipes and masts. They own and operate in a big facility consisting of different consecutively linked halls with a total length of 500 meter and a floor space of over 10.000 m2. All lighting within Coes is LED based. Transport within the company is also not a problem, Coes owns 2 overhead cranes up to 50 Ton hoisting capacity and several forklifts and trailers. In recent years they have developed an interest in circular economy transition and in 2019 they have installed 2298 solar panels. These solar panels deliver approximately 600 MWh renewable energy per year.

There are several processes that Coes uses to preserve metal constructions. The preservation process at Coes starts with cleaning the steel by means of abrasive blasting. Compressed air is needed for blasting, metallizing and coating (OSHA, 2014) . Blasting can be done by hand, blasting machine or a computer controlled blasting robot. Metalizing the blasted steel constructions can be done using zinc-, zinc-aluminum- and aluminum wire. Metallization is the process of thermal spraying an aluminum- or zinc alloy onto the blasted steel to coat and protect the metal longer and to increase the corrosion resistance. Lastly, Coes also coats the metal constructions that they treat. Coating is applied in their spraying halls, which uses a modern heating and ventilation system. Coating is also applied to increase the durability of the metal constructions.

2 The Problem

This chapter will focus on the problems at Coes. A problem cluster will be made to find the core problem, we will identify sub-problems, look at the gap between the norm and reality and of course discuss a problem solving approach.

2.1 Problem Introduction

Coes is looking into transitioning their supply chain from gas to electricity. The gas is mainly used for better climate conditions in their production facilities (1 big hall has infrared lighting powered by gas and 1 smaller hall has 3 gas heaters). The metal constructions lie in these halls. These constructions have undergone a blasting and coating process and must dry through the night, so they can be handled for the next layer of coating or for delivery to the customer, the next morning. Using the lights and the heating consumes approximately 100.000 $M^3$of gas per year. Coes would like to reduce their energy costs by either switching (at least partly) to electricity (reducing gas costs), storing solar generated electricity or a combination of both.

2.2 Problem Context

Coes Metaalbescherming is a company that receives big steel constructions from their customers to either blast, metalize or coat. This protects valuable assets and secures durability of the steel constructions. After coating the steel constructions, they must dry, because most of the time they will be picked up the next morning. This means that the temperature in the production halls must be regulated throughout the night which consumes a lot of energy (decreasing the heating will have a negative influence on the end-product). Because the heating relies mostly on gas, a lot of gas is used yearly. Coes would like to know if there is a technical and financially viable solution to make an efficient transition from gas to electricity in their supply chain.

2.3 Identification of the core and action problem

The theory of Heerkens & van Winden (2017) will be used as a general guideline to identity the core problem. A problem cluster will be made and every time that a problem is identified, we must ask ourselves if this problem may be the result of another problem. A fundamental problem will be found which can be influenced by the researcher and whose solution will make a real difference in the whole problem cluster. This is the core problem.

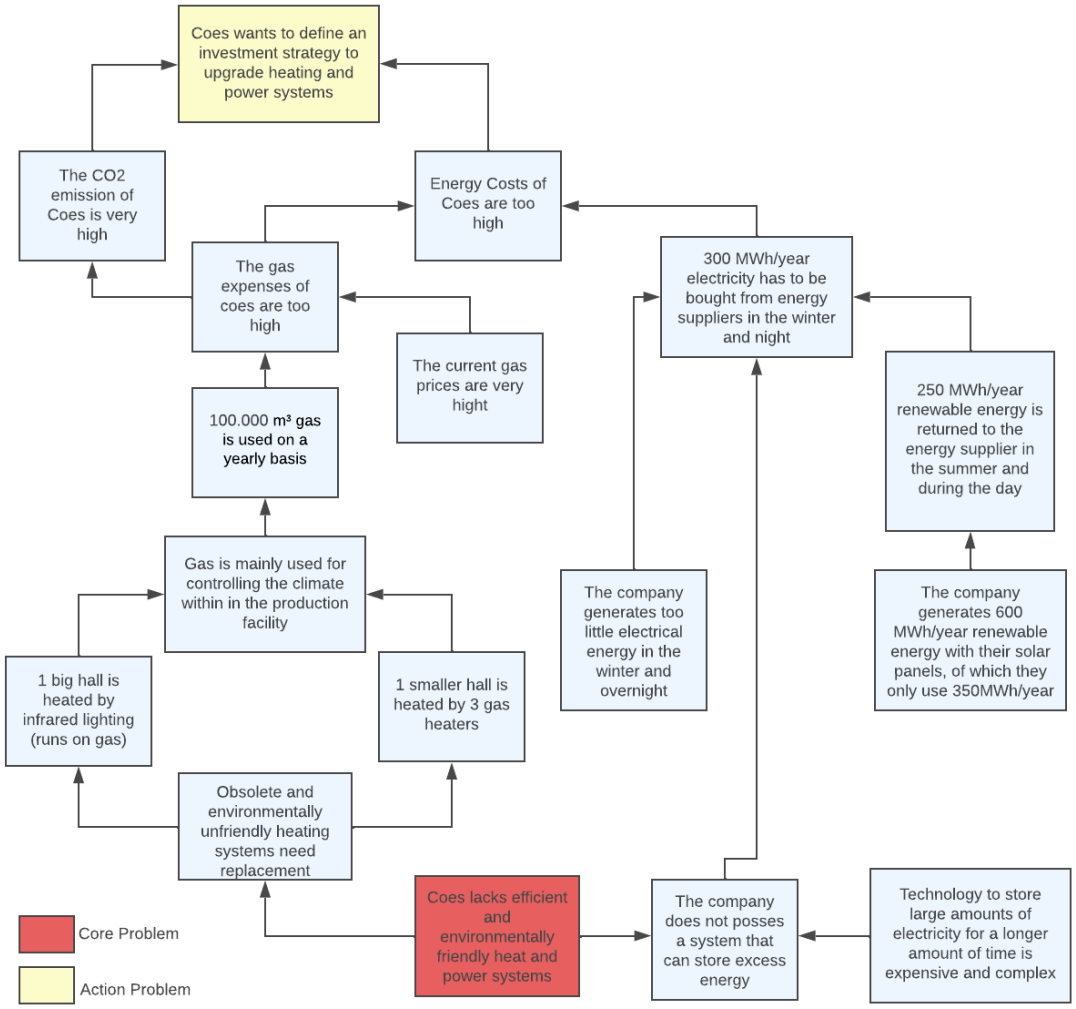

Figure 1: Problem cluster

2.3.1 Explanation of the problem cluster

In figure 1 the resulting problem cluster can be found. As has been mentioned before Coes is already interested in a circular transition and they would like to reduce their energy costs and CO2 emissions further. Most of the energy that they use is consumed by the heating systems. Also previously stated, they have infrared lighting, which uses gas, to heat one big hall and they have 3 small gas heaters to heat a somewhat smaller hall. This causes very high energy costs due to the amount of gas used in de supply chain in combination with the current gas prices. Heating is essential to the supply chain because most of the constructions that Coes processes must be ready at dawn so they can be picked up. Delivering constructions with coating that has not hardened yet is horrible for customer satisfaction and image because the steel will stick together. The gas heaters that are used are environmentally unfriendly and inefficient and even though the infrared lighting is more modern, it runs on gas, which is also inefficient and also has a negative impact on the environment.

Another problem that causes high energy costs is that the company has to buy electricity in the winter and overnight. Coes buys approximately 300 MWh electricity from their energy supplier. This is a tricky situation because the solar panels that were installed on their roof, produce approximately 600

MWh renewable energy per year. Only 350 MWh of this energy is used by the company themselves, so 250 MWh is returned to the energy supplier at a lower price. This feels like a waste because Coes would like to use that energy themselves so they won't have to buy the electricity back. In the Netherlands there is technology available that can store large amounts of energy without suffering too much energy losses over a time period of multiple months. The problem is that it is very expensive and complex to implement. Currently, Coes needs to buy energy in off-peak periods like the winter because the solar panels do not generate enough in that period. Even though they had a surplus in peak periods, for example the summer.

2.2.2 Selection of the core problem

Taking into account all of the mentioned problems in the problem cluster we can determine 1 underlying problem, with influence on the whole cluster. Both the energy storage and the gas problem have as an underlying cause that 'Coes lacks efficient and environmentally friendly heat and power systems'. This is the core problem because this is a fundamental problem that can be influenced and changed by a researcher. This automatically makes 'Coes wants to define an investment strategy to upgrade heating and power systems' our action problem.

2.4 Measurement of Norm and Reality

When an actor, in this case the company, has a problem it means that there is a situation with which they are dissatisfied. Of course the company has some idea on how they would like the situation to be and they strive for this. This is called the norm. But the company is dissatisfied because the current situation or 'reality' deviates from how they want the situation to be, the 'norm'. Such a deviation between norm and reality can only be solved by taking action and changing something about the situation, this is why we call such a problem an action problem. Alternatively, "An action problem is a discrepancy between the norm and the reality, as perceived by the problem owner" (Heerkens & van Winden , 2017).

In this case Coes is dissatisfied because of their energy costs and additionally their CO2 emissions. So their energy costs and CO2 emissions are too high which makes this the reality or current situation. As described before in the problem cluster this is due to the inefficient and unsustainable heat and power systems. This causes in its turn a high gas usage and the need to buy electricity in off-peak periods. This is also part of the reality right now. Lower energy costs and CO2 emissions is what Coes strives for, making that the norm. The discrepancy or divergence between norm and reality is quite clear. In order to bridge the gap between these two, action must be taken, or in this case the energy costs and CO2 emissions must be lowered. For example if we change the unsustainable heating systems into more sustainable systems we could lower gas usage and thus energy costs and CO2 emissions. This already reduces the gap between norm and reality significantly.

2.5 Problem-Solving Approach

In order to solve this research question, the Managerial Problem-Solving Method (MPSM) will be used. This problem solving approach was designed by Heerkens & van Winden (2017) to offer researchers a systematic approach to a problem, while giving them the space to think and act in creative ways. The MPSM also does not approach the problem as an isolated issue, it takes into account the context and actors surrounding the problem to come to a tailor-made solution. While the MPSM can be considered as a framework, it is still useful to do theoretical research to discover new methods, models and techniques that are applicable to the problem, because they can be integrated into the MPSM. This problem solving approach consists of 7 phases:

1. *Defining the problem*
   The first phase of the MPSM is defining the problem. This is done by defining the problem cluster, finding the core problem and then trying to determine a divergence between the norm and reality of the situation to find the action problem. This has already been done and can be found in chapters 2.2 and 2.3.
2. *Formulating the Problem-Solving Approach*

When the problem(s) have been determined a plan of action can be formulated on how to tackle the problems. We have already found the main research question and action problem, so now we can determine the sub-research questions (knowledge questions). These are defined in chapter 2.6. The problem solving approach will focus on the information that must be obtained at Coes and the expectations that Coes and both supervisors have of the research. Furthermore a theoretical perspective and framework will be made alongside an ethical analysis of the project plan. Together this will give a general guideline on how to approach the core problem.

3. *Analyzing the problem*
   Analyzing the problem means taking a closer look at the current situation at Coes. We will conduct qualitative research by doing interviews to determine where in the supply chain gas is used. We will also conduct quantitative research by looking at the numerical data gathered by the smart trackers that Coes uses. This way we try to understand the energy use and behavior of the company. We will also conduct literature research on the current gas and electricity prices to understand the development that the prices went through recently. Lastly we will also ask the company about possible constraints that they may have if we are going to implement a solution. For example: an implementation budget constraint or an time limit on the investment break-even time.
4. *Formulating (Alternative) Solutions*
   When we have analyzed the problems in detail we can start formulating (alternative) solutions. This means that we will conduct a lot of literature research. We try to find viable options for energy storage that Coes could implement. This includes an optimal capacity for the storage system and an operationalization plan for optimal use of the system. We will also try to discover viable options to make an energy transition from gas to electricity in the supply chain. We will also determine how much of the gas systems will have to transition. In the end we will come up with combinations of transition and storage solutions as the possible solutions to the problem.
5. *Choosing a Solution*
   When different solutions have been determined we must choose the best one. This is fully dependent on the vision and views of Coes. We already conducted research on the gas and electricity prices and we will try to predict the future behavior of the prices. We also already determined the energy use (behavior) of Coes and the operationalization strategy per energy storage solution. We will base a simulation on these values to find the optimal solution for Coes, Based on their KPI's and constraints. This will result in an optimal implementation combination of the storage and transition solutions and in addition an optimal storage capacity.
6. *Implementing the Solution*
   Using the simulation we came up with an optimal solution and an optimal storage capacity. We will ask for the opinion of both supervisors and the company on the proposed solution and the simulation used to get there. Based on the feedback received we will write a definitive recommendation for the company.
7. *Evaluating the Solution*
   The final stage of the MPSM will finalize the research. A combination of an energy storage system implementation and gas system transition has been chosen as a solution, including optimal capacity and operationalization. Recommendations have been made and are well argued and researched. The results, argumentation, conclusions and recommendations are made and the biggest findings are presented in a logical and clear structure to the company. We will acknowledge possible limitations of the solution and discuss my own view and interpretations on it.

In figure 2 the different phases of the Managerial problem-solving approach have been set out against the activities to be done during the different phases. The phases and activities are also linked to the intended deliverables obtained during the specific phase and activity.

Figure 2: Managerial Problem-Solving Approach

2.6 Research Questions

Right now a core problem has been defined and in this core problem we have determined a discrepancy between norm and reality. As explained above we turned our core problem automatically into an action problem. We can turn this action problem into our main research question. After the main research question has been composed, we can determine some knowledge questions. Knowledge problems describe problems where we have a lack of understanding or a lack of knowledge about the

problem. We must conduct research to obtain information and knowledge in order for us to answer the knowledge question. "A knowledge problem is a description of the research population, the variables and, if necessary, the relations that need to be investigated" (Heerkens & van Winden , 2017). These knowledge questions are formulated as the sub-research questions of the main research question.

2.6.1 Main Research Question

"Coes Metaalbescherming wants a technically and financially viable solution to make an efficient transition from gas to electricity in their supply chain to lower their energy costs and CO2 emissions"

Right now we have taken the core problem 'Coes Metaalbescherming wants a technically and financially viable solution to make an efficient transition from gas to electricity in their supply chain' and we added the gap between the norm and reality of the situation regarding the CO2 emissions and energy costs. It is impossible to directly answer this question so we will dissect it into smaller knowledge problems:

2.6.2 Sub-research Questions

1. "What is the current situation of the supply chain and the production facilities of Coes?
    a. "How is gas integrated in their supply chain and facilities?"
2. "Which scientific literature does already exist on energy transition and energy storage within companies that operate in a similar way and/or industrial field as Coes does?"
    a. "Which technologies do already exist for energy storage options?"
    b. "Which theories exist on operationalizing the energy storage?"
    c. "Which methods exist for transitioning gas systems to electric systems on a company scale?"
3. "What form will the simulation methodology take on and how will the simulation be created?"
    a. "What are the input and output values and what will the logic look like?
4. "What is the most cost-effective approach to implement a gas to electricity energy transition and an energy storage system in the supply chain of Coes?"
5. "What are the opportunities and threats of completely switching from gas to electricity?"

Every sub-research question has already been linked to a specific phase of the MPSM in figure 2. Below, is an explanation as to why there is a connection between the two:

- The 1st sub-research question is about the current supply chain and production facilities at Coes, so the current situation. This can be easily related to the 3rd stage of the MPSM, where we analyze and observe the current situation to determine problems and cause-relations.
- The 2nd sub-research question is about gathering and processing information and theories on the core problem. This is connected to the 4th phase of the MPSM where literature study is done to gather as much information as possible on all possible solutions for the core problem.
- The 3rd sub-research question is about finding a methodology that will be able to process all the gathered data and extract results out of it. We have already determined to use a simulation to get these results. This is related to the 5th step of the MPSM where we will establish the simulation by determining a simulation methodology and the logic behind it, that can convert our input values into the desired output values.
- The 4rd sub-research question is about defining the optimal solution based on the information and possible solutions that have already been acquired by using the simulation. This is connected to the 5th and 6th step of the MPSM where the optimal solution is determined by the simulation based on KPI's and constraints provided by Coes.
- The 5th and last sub-research question wants to know more about possible risks and opportunities of an energy transition. This is connected to the 7th phase of the MPSM, because we discuss possible limitations of the implemented solution here.

2.7 Definition of Key Variables

When you want to express a research question or solution, you will have to do that using variables. The solution to the research question will be the exact measurements of the variables and their

relationships. On these measurements you can base your conclusions and recommendations. This means that variables are measurables, but with varying degrees of accuracy (ReadingCraze, 2017). There are 2 different categories in which variables can be divided: dependent- and independent variables. Independent variables in an experiment are the variables that can be manipulated or changed by the one performing the experiment (McLeod, 2019). In no way, can these variables be affected by other variables, giving them their 'independent' status. Dependent variables are the opposite of independent variables. They are the ones being affected by their independent counterparts. A dependent variable is the variable that is being tested and measured during an experiment (McLeod, 2019). This makes KPI's dependent variables because we wish to improve the values of these variables by changing independent variables. The following dependent variables will be used as KPI's:

- Energy costs
- CO2 emissions
- Energy costs saved
- Breakeven point
- Financial risk

In the research question there are already 2 very important variables mentioned that we will use. The CO2 emission and energy costs are both dependent variables, which have, as already mentioned a gap between their norms and reality. By bridging the gap between norm and reality, the goal of the research can be successfully completed making these, two of the most important variables. Energy costs and CO2 emissions could both be used as KPI's in the simulation to find the optimal solution. Their values must be based on the wishes of the company. The amount of energy costs saved is also a dependent variable that can be used as a KPI. We wish to reduce the energy costs, in the simulation we can compare the energy costs of the original situation with costs after implementing a solution. Calculating the energy costs saved per solution could also be an important KPI. Furthermore the breakeven point of the investment can also be an important KPI. In our case the breakeven point is the point in time when the initial investment of for example a storage system and a couple of system transitions is earned back due to the money that we saved by implementing these solutions. The desired breakeven point can be determined by the company and used as an KPI in the simulation. Lastly, the simulation will determine different scenarios of the energy costs of Coes and it will take the average of these scenarios. We can do a risk analysis on this where the financial risk can also function as a KPI.

2.8 Theoretical Perspective

This section will be used to describe and explain from which literary perspective the research question will be approached. The goal will be to state the scope of what the research will address.

The main problem Coes faces is an energy transition and energy storage problem but to build a theory based on all different facets of energy transition and storage would be way to extensive. Besides a lot of research would be done on methods and theories that are not applicable at Coes. This is why the decision was made to already focus on theories of which we are sure that they could be implemented at Coes. As mentioned in the explanation of the variables the reduction of CO2 emissions and energy costs are dependent on the electricity and gas usage. These two can be reduced by investing in, and implementing, a storage system or technology and adding a structural method to use this implementation in the most efficient way. The theory that we will discuss in this project plan will mainly focus on such an implementation and the pros and cons of implementing it.

We will address the following two theories during the bachelor thesis:

1. We will look into electrical energy storage management, So the most efficient way in which Coes can store the surplus of electrical energy that is generated by the solar panels. So they will be able to use this energy for themselves. The research will also try to determine the optimal capacity of such a system and the operationalization of it.
2. The second subject this research will try to address is gas heating vs electrical heating. Gas heating plays a big role in the CO2 emissions and energy costs of Coes. Reducing this by switching to electrical heating systems could be a big part of the solution. Doing research on

the financial risks of switching to electrical heating and trying to find out what the best way is to implement new technology is going to be a main focus of this research.

2.9 Theoretical Framework

This section will give a quick but somewhat deeper insight in the actual theories that we will use to address the main research question. In order to make it easier to answer the main research question we dissected it into smaller sub-research questions. One of these sub-research questions was:

"Which scientific literature does already exist on energy transition and energy storage within companies that operate in a similar way and/or industrial field as Coes does?"

It is meant to discover all the literature and technologies that already exists on problems similar to the problem that Coes wants to solve. But this question on itself is also very broad and extensive, so in the paragraph on the theoretical perspective we dissected it again into two different main themes: Electrical energy storage management and gas heating vs electrical heating. For now will dive deeper into the energy storage theme. This does not mean that the main focus lies on this part. The gas vs electrical heating theme is just as, if not more important to the main research question. But there is also more knowledge needed on the actual heating systems and heating grid that Coes uses in their production facility. So for the sake of this project plan we will set out a theoretical framework around the subject 'electrical energy storage'.

2.9.1 Electrical Energy Storage

Nowadays, energy companies have taken the initiative to bring sustainable change to their customers, which are companies and regular households. They do an investment in for example solar panels and the generated energy is for their own use. On top of that if they generate a surplus of energy in peak hours, they can supply it back at a lower fee. A problem that a lot of customers, like Coes, have is that it is cheaper to store the energy generated in peak hours, and use it in off-peak hours. Otherwise customers still have to buy energy in off-peak hours at the normal fee. Because of the demand for a storage system, there have been developed some options for private households to store their surplus like small batteries. But the sheer amount of energy that needs storage and the energy loss that comes with storing energy, makes this option not viable for bigger companies like Coes. This theory will address some storage options that may be interesting to look into.

2.9.1.1 Battery Energy Storage System (BESS)

Batteries store and release energy using an electrochemical process. So technically they can act as an storage system. As discussed before batteries are a very viable option for private use. This is due to their initial investment costs and their fast responding dispatchable power. Logically, companies use and need a lot more power than the amount used by a regular household. So it is more interesting for companies to invest in a Battery Storage Power System. This is a power station that uses a group of batteries to store the surplus of electrical energy. The biggest pro of using BESS's is their fast dispatchability. Batteries can almost instantly switch from standby to full power when energy is needed. This is why they are widely used by companies as a stabilizer for their electric grids. If the electric grid of a company fails, the Battery Storage Power System can instantly take over the energy demand and fulfill this for up to a few hours. 'Various megawatt-scale projects have proved that batteries can respond more quickly and accurately than conventional resources such as spinning reserves and peaking plants' (World Nuclear Association, 2021). The shortcoming of BESS is that the energy can only be stored for a limited amount of time due to the energy losses, making it not a viable option for long term energy storage on a company wide scale. "Large battery arrays are becoming the stabilization technology of choice for short-duration renewables integration. This is a function of power, not primarily energy storage. So the demand for it is much lower than for energy storage' (World Nuclear Association, 2021). The BESS is great for managing small fluctuations, because it can store electrical energy for up to a few hours. In the case of Coes they would need it for storage of energy during the day so that it could be used overnight. The feasibility of this will depend on when

the energy will be stored, how long it can be stored and if the energy loss is not too great for the BESS to be already empty when it is needed in the night.

2.9.1.2 Thermal Energy Storage (TES)

Thermal Energy Storage is the process of storing excess thermal energy so it can be deployed and used at a later date. There is a wide range of different technologies involved and applied to this and the process itself takes on many different shapes and forms. Because of extensiveness of this particular method we will look closer into Seasonal Thermal Energy Storage (STES). This is the storage of heat for up to a few months and can be deployed at an industrial level to save and store waste heat. The fact that this technology can store thermal energy for a period of months makes it a very good storage option for Coes. 'Sensible heat storage is a comparatively mature technology that has been implemented and evaluated in many large-scale demonstration plants. Water, rock-sort material and ground/soil are frequently used as storage materials' (Xu. J, Wang, R.Z, Li, Y, 2014).The development of this storage option is as mentioned very mature, which reduces the risks involved in the process. Basically what happens is that the excess heat is stored in particular materials like water or rocks, that are capable of absorbing the heat and maintaining it. Then this heated material is stored somewhere in place that is highly isolated, for example under the ground. This way the heat losses are minimal. After a desired amount of the time it can be extracted again. The efficiency of this method is very dependent on how well the material can be isolated. Heat is just one of the many forms that energy can take on, so heat storage is just a form of energy storage. 'The stored heat amount is determined by the specific heat of the material and its temperature increase. Sensible heat storage is considered to be a simple and low-cost technology for seasonal energy storage'(Xu. J, Wang, R.Z, Li, Y, 2014). As mentioned before this could be a really good option for Coes for their seasonal storage problem. Using this method they could generate electrical energy in the summer. Transform it into heat and store it in another material in a highly isolated place. Then in the winter they could extract the heat and use it for heating their facilities. For example if they store the heat in water, they could let the water flow through the facility to warm it up. Another option would be to transform the heat back to electricity and then use it for other processes. But this could make the process unnecessarily complex and costly.

2.9.1.3 Mechanical Energy Storage

Mechanical energy storage systems take advantage of kinetic or gravitational forces to store inputted energy (American Clean Power Association, 2022). The Physics and reasoning behind the mechanical systems are most of the time basic and not very advanced but there is a catch. Building a machine or system based on these principles, that is able to store energy efficiently is very hard and expensive. The technology needed is very advanced and the computer control systems are cutting-edge. 'Currently, the most widely deployed large-scale mechanical energy storage technology is pumped hydro-storage (PHS). Other well-known mechanical energy storage technologies include flywheels, compressed air energy storage (CAES), and liquid air energy storage (LAES)' (National Energy Technology Laboratory, 2021). To give an example of how Mechanical Energy Storage works in general we will address the most basic form of mechanical energy storage: Flywheel Energy Storage (FES). FES works by accelerating a rotor or flywheel to a very high speed, using electrical energy. By doing so the electrical energy will be transformed and maintained as rotational energy. By increasing the speed of the flywheel energy can be added or extracted from the system. This works due to the principle of conservation of energy. Advantages of FES in particular are low maintenance, a long lifetime and the energy is immediately dispatchable. 2 Big disadvantage are that there is a short discharge duration and that an FES system has a small capacity.

2.10 Systematic Literature Review (SLR)

The systematic literature review can be found in appendix A.

3 Research Design

3.1 Type of Research

When we take a closer look again at the main research questions and the related sub-research questions, then we already see a chosen approach to solve the problem. We will be doing research at the facilities of Coes, so we can determine the current state of the company, and we combine this with literature research on energy transition and storage methods applicable at Coes. This way the research will try to discover more about the problem and its possible solutions by gradually exploring the subject further and further. We try to identify more variables and constructs, relationships between different variables and the effects they have on each other. This means that we will be conducting a mix of causal explanatory research and explorative research. 'In a causal-explanatory study, we try to explain relationships among variables'(Cooper, Donald. R, 2013). This will be done when assessing the situation at the company. When trying to explore the problem further and find appropriate literature for it, explorative research is done. 'Through exploration researchers develop concepts more clearly, establish priorities, develop operational definitions, and improve the final research design' (Cooper, Donald. R, 2013).

3.2 Research Participants

Staff-wise, Coes is a small company with not that many employees. They have employees for the different metalizing, blasting and coating processes of the supply chain. These employees either control a machine or do their jobs by hand. I intend to interview at least 1 employee per process to get and develop in depth knowledge on the specific process that they are conducting. This way I can estimate if there are other important energy flows going on in the supply chain that I don't know of. The way I see it, the employees have a lot of experience, they work in the facility every day and know a lot of details on how the machines and tools perform. I also intend to converse and discuss a lot with the business manager of Coes, who happens to be my mentor at the company. He knows a lot about the day-to-day business at the company and he could give insight on how all of the different processes are linked and integrated into each other. Lastly I would like to interview the director of Coes Metaalbescherming. Aside from the helicopter view that he has over the whole supply chain, he can give me a lot of new information on the technical side of the issues. He has a lot of in depth knowledge on the technology behind the processes, which could be very important to the research.

3.3 Data Gathering Methods

We will gather data at Coes in 2 different ways. First off all, as already discussed, we will interview employees, the business manager and the director. I intend to make some sort of questionnaire that will be used while doing the interviews. 'The interview is the primary data collection technique for gathering data in qualitative methodologies' (Cooper, Donald. R, 2013). This is important because Qualitative Research is described as 'collecting and analyzing non-numerical data (e.g., text, video, or audio) to understand concepts, opinions, or experiences. It can be used to gather in-depth insights into a problem or generate new ideas for research' (Bhandari. P, 2020) I would like to get insight in the behavior and the processes going on at the company. Most of all, every activity that has some sort of energy flow involved. This means that I want honest and realistic answers on the state of the company. The intended meeting time will be half an hour with the employees. I would like to speak with the manager and director a bit longer to get more in depth knowledge. There are not that many burdens involved in interviewing the employees. But I will discuss having the interviews with a supervisor, so the day-to-day business and planning will not be interrupted. Of course if certain participants do not feel comfortable with certain questions they will not be forced to answer.

The second data gathering method will make use of the smart trackers that the company has already installed. Using these smart trackers Coes tries to get insight in their energy use and their carbon footprint. The system connected to the trackers is called Verdura and by accessing their app you get an overview of the energy use behavior. The data that the trackers have gathered and the overview of this in the app are a great example of numerical data on the current energy use of Coes. Numerical data is an example of Quantitative research. 'Quantitative research is the process of collecting and analyzing

numerical data. It can be used to find patterns and averages, make predictions, test causal relationships, and generalize results to wider populations' (Bhandari. P, 2020). This can help me identifying trends and patterns in the behavior of the company. The company self can choose which systems and processes to add and track. The trackers continuously provide information on how the company is performing based on energy saving and CO2 reduction goals. It shows improvement in graphs over a certain time period and it predicts what impact, management decisions will have on the CO2 emission. Furthermore it makes elaborate and dynamic reports of the current situation and provides trend analysis on past behavior. These functions give me a great image of how the company is performing right now and also give insight in the effects that certain implementations could have on the supply chain of Coes. At this point it is not clear if verdure also tracks gas and electricity prices. In order to still be able to find historical data on energy prices we will use the market data gathered by EEX or Nord Pool.

3.4 Data Analyzing Methods

During the research phase we will gather 3 types of data: the answers to the interview questionnaire, literature and numerical data:

3.4.1 Answers to interview Questionnaire

As mentioned before, interviewing people is a qualitative research method, which means that the data gathered needs to be interpreted by the interviewer first. This way patterns and trends can be discovered. It is important that the notes and questionnaire answers that are made during the interview are viewed and analyzed as fast as possible. This way the interview itself is still fresh in the mind of the researcher, which means that while viewing the notes the researcher is still able to give context to the situation. The questionnaire will be made to give a general structure to the interview, but there is room for the interviewee to state their opinions and give additional information. The questions asked are very similar and they intend to give insight in the current situation at Coes. They will be about how the processes work, which machines will be used and the function of the machines. The questions are meant to give insight in how the supply chain works and the relations between the machines and the processes. Based on this information we can build the simulation. The better and more in depth the questions are the more accurate the simulation will be. By making an accurate simulation we yield more reliable and trustworthy results, because the reality is better represented.

3.4.2 Literature

In order to find literature and theories, we use Systematic Literature Review (SLR). As mentioned this can be found in the appendix. SLR is mainly focused on systematically finding literature and reviewing the sources of the literature. By using a key concepts and synonyms in a search matrix, we try to find as much relevant content as possible on a particular research subject. Then when we find new literature and data we must still review it and find which sources are more important or relevant than others. This is done by looking at the trustworthiness of the sources, so we can determine the quality of the data. The literature research done will mainly gather information on the implementation options for energy storage and on energy transition option from gas to electricity.

3.4.2 Numerical data

Numerical data has been already determined to be quantitative data. The numerical data can be found in the tracking program that Coes uses called Verdura. As mentioned before the app already provides a lot of insight on the current situation at Coes. It has a build-in trend analysis function and is able to make very elaborate reports on the situation. It also shows what the impact of certain decisions will be on the CO2 emission and energy use. This way we can also analyze which systems have an influence on which processes. We can explore the relationships in the supply chain and the program searches for existing patterns. We can base the simulation partly on the relationships that have already been determined in the app. I predict that a lot of the numerical data analysis will be done using Verdura. Furthermore we will take a look at the historical gas and electricity prices, so we can make a prediction on the future behavior of both of these.

3.5 Data Processing Methods

Now that we have gathered the data and analyzed it, we have to process it. This is the step where we will turn input data into the desired output data. As mentioned before we will use a simulation to do this for us. In this section we will describe what the simulation is going to look like, what the logic behind it is and the main input and output values of it.

As previously stated, we will gather historical data on the gas and electricity prices from energy markets like EEX and Nord Pool. We will extract information from this data, mainly 2 parameters: the volatility and the drift. These 2 parameters can be used to make a Geometric Brownian Motion, which is a continuous-time stochastic process in which the logarithm of the randomly varying quantity follows a Brownian motion. This is used in mathematical finance to model stock prices. Using GBM we can now make a prediction trajectory of what the future gas and electricity prices are going to look like. We will make a Monte Carlo simulation to predict about 100 trajectories of the price behavior per month for example over the next 10 years.

Using Verdura and the interview notes, we have established which processes use gas and which processes use electricity. We also know how much energy is used and when so we can make an estimation of the average gas and electricity use per month in the original situation. In addition we can make an estimation on the average CO2 emission per month. Now the simulation can combine the predicted energy behavior with the gas and electricity predicted trajectories into an overview for the expected energy costs per month for every price trajectory. This is all for the original situation, meaning the predicted situation of not implementing any solutions. Because of the fact that we run a Monte Carlo simulation we can combine all the trajectories to get an overview of the average gas and electricity use per month.

Now that we have established that, we can focus on the solutions that we could implement. We calculate the effects that a solutionX could have on the energy behavior and the CO2 emissions. This gives us predicted values for the gas use, electricity use and CO2 emission if we implement solutionX. Again we combine this with the gas and electricity predicted trajectories to get another overview for the expected energy costs per month for every price trajectory. Only this time it is a prediction overview for SolutionX. We can compare the averages of these overviews with each other. For example, if we do the ‘total predicted average energy costs of the original situation’ minus the ‘total predicted average energy costs of the solutionX situation’ we get ‘the total predicted average energy costs saved’.

Now we can compare total energy costs of the solutions with each other and the total predicted average energy costs saved of the different solutions. We can also determine the breakeven point, because that is the point in time where Investment costs (SolutionX) = Total predicted average energy costs saved. This means we can compare the breakeven points of the solutions with each other. We can also compare the CO2 emissions of the different solution with each other and with the original situation. Finally, we can estimate a financial risk based on all the different trajectories of the energy costs. Because we have thus far mainly used the averages of these trajectories.

Lastly, we want to optimize the capacity of the energy storage system. This system has a operationalization and certain behavior assigned to it. This also influences the energy behavior of the company. Such a storage system also has influence on the implementation costs and the gas and electricity use. This in its turn influences different KPI’s like breakeven point, energy costs, CO2 emission and energy costs saved. By changing the value of the capacity we influence our KPI’s, which means that we can find a value for the capacity that optimizes our KPI’s.

3.6 Deliverables

The main deliverable will be the simulation with all the historical data gathered implemented in it. It will be able to draw different scenarios for the energy costs based on the input data. These values are mainly the gas and electricity usage of the company. It will draw all of these scenarios in tables on

excel and take from it the predicted averages. This information is used to create the output. It will calculate the KPI's: the energy costs, energy costs saved, CO2 emission, breakeven point and finally the financial risk. Based on these KPI's and the goals that the company has set for these KPI's we will determine the best solution. Another deliverable will be a substantiated recommendation based on which solution has performed best in the simulation. We will also calculate an optimal capacity for the energy storage system and an operationalization guide will be delivered in addition. The final deliverable will be the final report and colloquium.

3.7 Validity and Reliability

3.7.1 Validity

Validity is very important to the trustworthiness of a theory, conclusion or concept. It is the extent to which, for example a theory, accurately represents the real world. The better it corresponds with the real world, the better grounded the theory is. Validity comes in 2 main forms: internal and external validity. : 'internal validity —do the conclusions we draw about a demonstrated experimental relationship truly imply cause?—and external validity —does an observed causal relationship generalize across persons, settings, and times?' (Cooper, Donald. R, 2013). Underneath here we will give some examples applied to Coes.

While performing the research we must make sure that the conclusions are internally and externally valid. So the causal relationships that are assumed must be proven to be true. An easy example would be the relationship between gas use and CO2 emission. It is common knowledge that an higher gas usage accounts for an higher CO2 emission. This works the same way with gas use and energy costs, the more energy you use, the more you have to pay. But we must also be able to prove for example that by replacing the unsustainable systems at Coes, we will be able to reduce gas use. An example of external validity is that if the research is completed and we have reduced the CO2 emissions and energy costs, that we will be able to solve the same problem at a different company that is similar to Coes. The solution to the problem must be the same implementation. This accounts for external validity because if this works, the theory and its conclusions are generalizable.

3.7.2 Reliability

Reliability is the degree to which a method or measure instrument can supply consistent results. 'Reliability also is concerned with estimates of the degree to which a measurement is free of random or unstable error. Reliable instruments can be used with confidence that transient and situational factors are not interfering' (Cooper, Donald. R, 2013). Reliability contributes to the validity of a theory but it does not account for it. An example that could represent this situation is as follows. You are able to measure and prove consistently with the simulation that an energy storage capacity of 150 KWh yields the optimal energy cost reduction. But the results do not correspond with the reality of the situation, because we save a lot less money than was simulated. This means that even though the method of measurement is reliable, it is still not valid because the results are wrong. When conducting research for Coes we still must make sure that the results are reliable. One of the best ways to do this is by ensuring that the simulation consistently produces similar results when the same input values are used. Also while gathering data we have to make sure that the interviews are conducted in a similar way and that the questions asked are consistent and similar, this way the simulation will be based on accurate information based on the real life situation.

3.8 Limitations

When conducting research it is very important to state the limitations of the methodology, implementation strategy or theory, in advance. Trying to ignore limitations is an unprofessional attitude that can even be considered as unethical at some point according to Donald R. Cooper (2013). So right now we will state some possible limitations of this research approach. First off all, this way of researching is very sensitive and prone to human errors. This is because a lot of information will be extracted during the interviews. The researcher could misinterpreted the information provided, or the interviewee could provide wrong information themselves. Even if both of these scenarios do not occur,

there could still go something wrong due to plain miscommunication. The result is that wrong conclusions can be drawn about how gas is used in the supply chain. This will make the simulation less reliable because it does not represent the reality of the situation. The researcher should be aware of this and try to minimize the possibility of such errors occurring, we already mentioned that this will be done by conducting the interviews in a similar manner with a similar structure.

A second limitation is that most of the information will be provided by either employees and supervisors of Coes or data programs used by Coes. The information received by the researcher could be very subjective. For example if processes are described as more efficient than they actually are then these values will also be used like that in the simulation. Then the results of the simulation will differ from the real results because there are small differences between real life processes and the simulation. In order to counter this the researcher must be very attentive of this limitation during the literature study phase of the research. This way he can adjust his judgement by using objective sources.

A last limitation of this research that I predict to be quite hard to ignore is the current gas prices. The simulation will base the recommendations and conclusions on the simulation. The simulation in its turn bases its values partly, on the prediction of the future gas prices. The future gas prices are predicted using the current behavior of the gas prices. Here lies the main limitation, the gas prices are extremely fluctuating, so trying to determine future behavior using past data is going to be quite hard. We must take into account the influence of real-time events going on in the world right now. Because if we do not the simulation does not accurately represent reality and thus it will result in wrong recommendations for Coes. There is also a small rsik of not being able to find the desired historical data on the gas and energy prices. We will try to acquire them from either the data of Vendura or from energy markets like EEX and Nord Pool.

3.9 Gantt Chart

To give an idea of the intended progression I want to make through the weeks, a small and general time planning has been made. This is in the form of an Gantt Chart and can be found underneath here in figure 3.

Task Name	9/1/2023	16/01/2023	23/01/2021	30/01/2023	6/2/2023	13/02/2023	20/02/2023	27/02/2023	6/3/2023	13/03/2023
Interview director										
Interview employees										
Processing interview notes										
Processing Smart Tracker data										
Literature research on gas prices										
Literature research on electricity prices										
Literature research on storage systems										
Literature research on gas electricity switch										
Making predictions on future energy prices										
Building simulation										
Run simulation and draw conclusions										
Ask for feedback										
Implement feedback										
Write final report and present recommandations										

Figure 3: Gantt Chart

4 Philosophy of Science and Business Ethics

4.1 Motivation of Research Design

This research design has as a main goal to make a circular energy transition at Coes. This means reducing the CO2 emissions and energy costs. We intend to do this by replacing and implementing new heating systems and looking for a way to store the surplus of electrical energy generated by Coes. The research design is divided into 3 parts: assessing the current situation at Coes, doing literature research to try and discover theories that are applicable at Coes and finally choosing a solution from these theories. Assessing the current situation at Coes is done in 2 different ways: we will be interviewing employees and we will look into the data that their smart trackers have kept track off. These are the main data gathering methods of the research design.

As mentioned in the research design the main data gathering and data analyzing methods are a mix of qualitative- and quantitative research. The qualitative research is performed by doing structured interviews with employees and analyzing the notes and also by having a semi-structured dialogue with the business manager and the director. The quantitative research is performed by looking at the data in the app connected to the data trackers. Then we will analyze this data to try and find patterns in the energy use. This way we can hopefully predict and influence future data. Combining these two research methods will give us a good image of the current state of the company and will help us finding more fitting solutions.

First off, we will substantiate the choice for interviews using a philosophical view called 'constructivism'. Constructivism is 'the view that the entities in some domain exist, but are mind-dependent in the sense of not existing over and above our construction of them' (Ladyman, 2001). What this means is that there is a difference between our knowledge about reality and the actual natural world we live in. In order for us to try and understand reality, we try to measure and construct concepts about our sensory experience of it. According to constructivism, the actual world is independent of human minds and the theories that we construct, but our knowledge about the world is in all cases a social construction. What in its turn means that every human being has their own truth about reality. The interviews that will be conducted must be from this point of view, to make them as objective as possible. All of the interviewees experience the current state of Coes in their own way. The knowledge that they have about the company is constructed by themselves and is their own truth about reality. By realizing and accepting this as a researcher, the research can be more objective because every 'opinion' and every 'view' is seen as a truth for the person being interviewed.

Secondly, we will substantiate the choice for gathering and analyzing numerical data by using the concept of paradigms, in particular the paradigm as a disciplinary matrix. 'A scientific paradigm is a framework containing all the commonly accepted views about a subject, conventions about what direction research should take and how it should be performed' (M. Shuttleworth, L.T. Wilson, 2008). The concept is explained in a similar way by Ladyman (2001). Within a scientific domain there a some fundamental questions that need to be answered before research can be executed. For example: What kind of things exist in the universe and how do they interact with each other, what are legitimate techniques to answer research questions and when does something count as evidence. 'A disciplinary matrix is a set of answers to such questions that are learned by scientists in the course of the education that prepares them for research, and that provide the framework within which the science operates.' (Ladyman, 2001). The numerical data provides information on the energy use of Coes. By analyzing this data we want to determine patterns and build a simulation based on this information. There have been developed a lot of theories on how to extract information from numerical data, how to analyze it and how to draw the right conclusions from this. The numerical data analysis that we intend to perform exist within the scientific paradigm of data processing. Using the methods, theories and techniques that have been acknowledged within this specific scientific field will help to validate this research design.

4.2 Research Ethics

Something to be very mindful of while conducting any form of research is to perform every action in an ethically responsible way. There are enough examples of research that has been conducted in an ethically grey area, reasoned from a contemporary perspective. Of course it is unacceptable to work this way because the research is based on data that has been generated in a unethical way. This means that the research group or the participants in the research have been treated unfairly or in the worst case scenario have been harmed physically or mentally due to the research. Exactly for this reason there has been written and published a 'Netherlands code of conduct for research integrity'(2018).

We will dive somewhat deeper into the scope of the 'Netherlands code of conduct for research integrity'. It is a code of conduct that applies to and is mandatory for activities that are 'both publicly and privately funded research, be that fundamental, applied or practice-oriented' (Netherlands code of conduct for research integrity, 2018). It applies to individual researchers, including PhD students, visiting researchers supervisors and everyone else within an educational setting. Logically it will also

apply to this project plan and in the future to the bachelor thesis that will be the result of this project plan. The code of conduct is based on the following 5 widely supported principles of integrity: Honesty, Scrupulousness, Transparency, Independence and Responsibility. Besides that the document also defines 61 principles for the quality of the research. In order for this project plan to meet the ethical standards required, we will send it to the ethics committee of the BMS faculty for approval. This approval can be found in section 4.6.

The research design starts with interviewing employees. When the researcher is conducting the interviews, the principles of honesty and transparency are the most important. Honesty in this context means putting down on paper what the interviewees say with as much accuracy as possible. Taking every counterargument, opinion and critical comment seriously and not twisting words or making unfounded claims. This way the research respects the data provided by the employees. Transparency in interviews would mean, informing the employees about the topic that will be discussed and about how it relates to the research. Furthermore telling them exactly the goal of the research, so they know how it relates to the questions. This way the employees feel more respected because they know how their answers will contribute to the research.

Secondly comes the numerical data analysis. When analyzing the data it is important to use the principle of scrupulousness. It is important to use methods that are scientific or scholarly. It is also of interest 'to exercise the best possible care in designing, undertaking, reporting and disseminating the research'(Netherlands code of conduct for research integrity, 2018). It is important to use scientifically proven methods in data processing because it makes the analysis and conclusions more valid and reliable.

Lastly when reporting the findings and results back to the company it is also important to be honest and transparent. In this context honesty means, reporting the research process as accurately as possible back to the company, so they understand the choices made by the researcher. It also means 'refraining from presenting results more favorably or unfavorably than they actually are' (Netherlands code of conduct for research integrity, 2018). Transparency is closely related to honesty in the sense that it wants to ensure that, how the data was gathered and which sources and methods were used, are reported very accurately back to the company. This way the company can form their own opinion based on objective facts.

4.3 Professional ethics

4.3.1 Professional Responsibility

To determine my professional responsibility when working on my bachelor thesis at Coes, we will first determine the definition of professional responsibility in general. Professional responsibility means 'those programs or segments of programs devoted to a) the substance, underlying rationale, and practical application of the Rules of Professional Conduct; b) the professional obligations of the researcher to the company, the public, and other researchers; c) moral philosophy and ethical decision-making in the context of the research.' (Lawinsider, 2022).

So the researcher must act in a professional manner within the company. He must follow the general and company specific code of conduct and he has an obligation to the company, public and other researchers to act and conduct research in an ethical way. In this case I will be hired as an intern at Coes to conduct research for them about their supply chain. At this point in time I must accept that I have barely any knowledge about the company or their way of working. This means that I owe it to them to get to know the company as good as possible within the given timeframe, so that the research that I will deliver to them will be of excellent quality.

My biggest responsibility besides learning about the company will be good communication. There are different actors and stakeholders within the bachelor thesis like the university, supervisors and most importantly the company. Logically it is expected from me to communicate well with all the different actors. The company deserves to be informed about the progress of the research as they are the ones

investing time and money in me and my bachelor thesis. So it is my responsibility to give them updates about the work and inform them and involve them in the decision making process.

Lastly I must follow and respect the code of conduct of the company. I will act accordingly to the guidelines and rules when I am at their facilities and most important of all I will treat the company, their employees and their machines and tools with the respect that they deserve. I am a guest at the company, meaning that I should act in accordance to that term.

4.3.2 Code of Conduct

In the research ethics we already discussed the Netherlands code of conduct for research integrity, a general code of conduct that every researcher that wishes to conduct any form of research in the Netherlands has to follow. As mentioned these are general rules for everyone. But companies have almost always their own code of conduct for their employees. These are general guidelines and rules about the type of behavior that is expected of employees when they start working at the company. It gives them an third parties an idea on how a company wants to represent itself and the principles that they have.

Coes also has such a code of conduct these are their 'Coes Metaalbescherming Huisregels'. There are a lot of general rules and arrangements about salary, absence, vacation days and much more things that do not specifically apply to a bachelor researcher. But they also have very strict safety rules, which are to be expected of a professional company within the metal processing sector. These passages out of their code of conduct will apply the most to me. If I am going to be on location to observe their work, interview the employees and inspect the machinery it is expected of me to know their safety rules and follow them precisely. It is logical that some unsafe situations could arise with all of the internal transport, big machines and chemicals used. So as not to harm myself, employees or any machinery I should become familiar with the rules and I should respect them.

4.4 Social Impact

Lastly, social impact is also a very important part of the philosophy of science and business ethics. It is focused on identifying stakeholder within the project and anticipating the social impact that this research might have on them. We will focus on the influence and power that each stakeholder holds over the direction the research will go in. Furthermore we will look closely at the importance of the research for different stakeholders.

4.4.1 University of Twente

The research will be performed on behalf of the university and in the end they will be the ones to publish the research. The research on itself is not a very big interest to them. Their main goal is to provide the tools and support system so that students can learn and graduate. In contrast to that they have quite a bit of power over the direction of the research. In the end they will determine if the thesis is sufficiently done and they provide a framework for how to approach a bachelor thesis.

4.4.2 Coes Metaalbescherming

Coes has a lot of interest in the research. This is because the simulation and recommendations provide insight in their company. They receive an implementation recommendation with an operationalization plan so they know what options they have, and the best choice out of these options. Besides that they have the power to decide to use the research or not. They also have power over the direction the research will go in. The research will also be performed on their behalf and the KPI's and goals will all be in their best interest. So dependent on their stance, particular decisions will be made.

4.4.3 University Supervisor

The main goal of the university supervisor lies close to the main interest of the university. He is my main point of contact provided by the university. He has specialized knowledge on the subject and can help me with the problems I will encounter. His goal is to help me graduate, and do so using

academically and integer methods. He has a lot of power over the research because he will be the one grading this project plan and later on the research thesis. His advice and recommendation will be taken seriously and will be implemented during the writing of the thesis.

4.4.4 Company supervisor

My company supervisor is the business manager of Coes. He already manages the CO2 reduction of their operations and he oversees and has insight in the smart trackers and tracking program that the company uses. He will be my main point of contact of the company and he will provide me the most insight in their operations. He shares the same interests as the company and wants to know more about possible implementation options. He has also a lot of power over the research because he will guide me in my research from the perspective of the company. He is the one that will vocalize the wishes and goals of Coes.

4.5 Conclusion

In conclusion, it is of utmost importance to understand as a researcher the responsibility you have in regard to different stakeholders. The thesis is performed by me with as end-goal to graduate. The university provides me the tools and guidance to do so. The company, in contrast to that, hired me to perform research for them so that they can base decisions on the results and information provided by me. This is a big responsibility entrusted to me and I should treat it as such. As mentioned before I am also a guest at the company, this means that I have to show great respect for the rules and code of conduct that the company has. This is not only for the safety of me and my environment but also to show that I appreciate the aforementioned trust that they have put in me.

Besides the company specific code of conduct there is also a general code of conduct in the Netherlands. It describes how I should act as a researcher and how I can perform my research in an ethically right way. This has a big influence on the way I will conduct my interviews for example, because the interviewees must feel comfortable when they answer the questions. The general- and company specific code of conduct together describe the professional responsibility that I have and how I must behave in order to be a professional. Together these rules give an image of what behavior the company expects of an employee and what behavior is academically and ethically expected of a researcher in the Netherlands. By knowing this and behaving in accordance to these guidelines I can approach this bachelor thesis with confidence in my methods and professionality.

4.6 Approval of Ethics Committee BMS

9. CONCLUSION

Status: Approved by commission

The BMS ethical committee / Domain Humanities & Social Sciences has assessed the ethical aspects of your research project. On the basis of the information you provided, the committee does not have any ethical concerns regarding this research project. It is your responsibility to ensure that the research is carried out in line with the information provided in the application you submitted for ethical review. If you make changes to the proposal that affect the approach to research on humans, you must resubmit the changed project or grant agreement to the ethical committee with these changes highlighted.

Moreover, novel ethical issues may emerge while carrying out your research. It is important that you re-

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consider and discuss the ethical aspects and implications of your research regularly, and that you proceed as a responsible scientist.

Finally, your research is subject to regulations such as the EU General Data Protection Regulation (GDPR), the Code of Conduct for the use of personal data in Scientific Research by VSNU (the Association of Universities in the Netherlands), further codes of conduct that are applicable in your field, and the obligation to report a security incident (data breach or otherwise) at the UT.

5 Feasibility and Personal Development Plan

One of the most emphasized skills that we learned in the Bachelor of Industrial Engineering and Management is to become a self-directed learner. It was very understandable, knowing that this skill could be a great asset in almost every aspect of life. This is why there was also a big emphasize on it during module 11 As we have seen and learned in the lectures it consists of 2 parts: motivation and self-knowledge. Both of these qualities are equally important towards the goal of becoming a self-directed learner. During this module it was expected of students to manage themselves and take initiative. There were not that many deadlines and all of the work that would be done by the students led towards learning how to approach the bachelor thesis. This way of working made sure that I became a better self-driven learner.

5.1 Self-Motivation

To become better at learning, you need to know what drives you. You need to understand the core values of your motivation. Some subjects are easier to spent time on then others, it has to do with your interests. Some people can get more work done in the morning, while others are more productive in the evening, rhythm says a lot. There is also a difference in the purpose or end-goal in which you invest your time in and some goals are more important to you then others. This is a reflection of the values that make you the person that you are. This is the motivation or engagement part of being a self-directed learner. In order to improve this, you need to become more aware of these aforementioned values. The more you know about yourself and your behavior, the more you can implement certain practices to direct your behavior towards generating intrinsic motivation.

I noticed that by setting smaller deadlines for myself while working on the project plan really worked. It gave me enough satisfaction when I met a deadline and gave me the motivation to work towards the next. Planning deadlines before the weekends so that I could relax in those weekends also gave me enough stress-relief to pick the work back up on the next Monday. I also noticed that after a few weeks I developed a rhythm that helped me in giving my working days more structure. Having a structure and knowing what needs to be done every day really helped in keeping myself motivated, while I was also able to easily lay down the work when I had finished it. During this module I really learned how to efficiently manage my time while still keeping myself motivated for the next tasks. I also learned how to adjust my own behavior to keep the motivation sustainable.

5.2 Self-Management

In the previous Alinea I already mentioned how having a structure during the day and having a smaller deadline to work towards to really helped me in keeping my motivation up. If I got a big deadline coming up I divided it into different subjects that each had their own deadline. After that I could make a small planning of what tasks I would do on which day to be able to meet the deadlines. I noticed that I worked the most efficient during the afternoons and I got the most work done between 13:00 and 17:00 during the day. The mornings helped in setting myself straight: looking at the tasks for the day, reading emails, and rereading what I had written in the previous day. This helped me be more effective in the afternoons. In the afternoons I worked on the tasks that I had previously had set for myself. I tried to be finished before dinner so that I could relax in the evenings and sometimes meet with my buddy.

This strategy worked for me because I worked towards small goals that could be achieved in small time intervals. After a day of work it was easy to let the work and stress go because I had confidence in my planning, if I followed my planning I never would encounter any time problems. This made my personal time more rewarding and helped me in resting and relaxing. Having a clear structure and distinction on which time would be invested in work and which time would become personal time, really helped me in being more effective in both of these things. In the end this gave me an intrinsic motivation to work, while also being able to maintain this motivation because I set small rewards.

5.3 Self-Monitoring

During this module I discovered the cycle of becoming an self-directed learner more in depth. I can influence my motivation levels by managing my time planning. But this is a process of trial and error. Every study session, I try studying in different ways, settings and time periods, and after a study session I can analyze what worked for me. By monitoring my study behavior and giving myself feedback on it, I learned to improve my study sessions. By constantly repeating this cycle, I learned to work more effectively and efficiently. The most important part of this whole process is being aware of the things I do and later on reviewing, this is the self-monitoring part. This will be very important when I start my bachelor thesis in module 12. The kind of work that I will perform will be different so I will have to find a rhythm again. I will do this in the same way as I just described, the way I approached module 11. By self-monitoring my own progress I can keep track of what I achieved per day and how I managed to achieve it. By repeating this cycle of monitoring my behavior and improving my self-management based on this, I can find and sustain my motivation.

Appendix

Appendix A: Systematic Literature Review

Appendix A.1 Defenition of the knowledge problem

In this section we will try to find existing literature and knowledge on one of the sub-research questions that we have established. We will do this in a methodical way using a 'Systematic Literature Review' or SLR. The sub research question that has been chosen is:

"Which scientific literature does already exist on energy transition and energy storage within companies that operate in a similar way and/or industrial field as Coes does?"

Appendix A.2 Inclusion and Exclusion Criteria

Consulting the micro-lectures on SLR we have concluded some inclusion and exclusion criteria. These criteria show for example which keywords need to be included in the search string to cover the research topic. But also the search language and the credibility of an article.

Nr.	Criteria	Exclusion or Inclusion	Explanation
1.	Language: English	Include	Most accepted language in scientific research. Also most used language for communication.
2.	"Energy Storage" OR "Electrical Energy Storage"	Include	Main keywords of this research.
3.	Studies about "Industrial energy storage" OR "energy storage for companies"	Include	We are looking for energy storage on an industrial- or company scale
4.	Studies about "Domestic energy storage" OR "private energy storage"	Exclude	A lot of research is on small energy storage options for private and for household consumption. These are not viable options for a company of the size of Coes.
5.	Articles between 2005 and 2022	Include	In the year 2005 the Kyoto protocol enters into force. This protocol legally binds developed country parties to greenhouse gas emission reduction goals. This means that countries were forced to do research on sustainability, starting a rapid development phase on the subject.
6.	Pre-2005 articles with less than 15 citations	Exclude	These articles are not reliable enough and the technology used is to outdated to be considered in this research.

Appendix A.3 Determination of Databases

For this research we will use the databases of Google Scholar and the University of Twente Library. Google Scholar is used because of the extensive result lists that are provided when the input consists of general search strings. We use the Utwente Library because almost all of the results are credible and we may be able to find literature on geographical nearby examples.

Appendix A.4 Search terms and used strategy

First off we will create a search term matrix. This will provide an overview of the keywords and terms used in the search strings that we will make. By looking at related terms and synonyms we can make the search broader and more extensive.

Construct	Related terms	Narrower terms
Theory	Method, approach, systems, options	Energy storage options
Energy storage	Cache, depot, storehouse	Electrical Energy storage, Thermal Energy Storage, Mechanical energy storage Kinetic energy storage
Industrial	Applied to companies, not private, on a company scale	Industrial energy storage systems
Seasonal	For a longer duration, long-terms	Seasonal energy storage

Now we will create a search matrix in which we will present the search strings that we used to get to the results that we found. It will show the progress on how we narrowed down the search results and how we refined the search strings based on that.

Search String (plus additional search functionalities or	Scope	Date of Search	Number of results
Google Scholar			
((electrical* OR Thermal OR mechanical OR kinetic) AND “Energy Storage” AND (method* OR theory OR approach O R system OR options) AND (LIMIT-TO (LANGUAGE , "English"))	Topic	December 3rd 2022	2700
((electrical* OR Thermal OR mechanical OR kinetic) AND (Seasonal* OR long-term OR long term OR For longer duration) AND “Energy Storage” AND (method* OR theory OR approach O R system OR options) AND (LIMIT-TO (LANGUAGE , "English"))	Topic	December 3rd 2022	555
(Thermal AND (Seasonal* OR long-term OR long term OR For longer duration) AND (“Energy Storage” OR “energy cache” OR “energy depot” OR “energy storehouse”) AND options AND (LIMIT-TO (LANGUAGE , "English"))	Topic	December 3rd 2022	433
University of Twente Library			

Energy Storage options	Topic	December 4th 2022	19400
Electrical Energy Storage options	Topic	December 4th 2022	14100
Seasonal thermal energy storage	Topic	December 4th 2022	2800
Articles found on Google Scholar			8
Articles found in the University of Twente Library			3
Snowballing			1
Articles for closer review			7
Total number of articles after closer review			**5**

Appendix A.5 Concept Matrix

Using the search matrix table we previously made, we will now use it to create the following matrix table. It will review the articles and sources found during the search process.

Titles	Authors	Date	Key Findings
"Electricity and Energy Storage"	World Nuclear Association	2021	How electrical storage works. All the different forms in which electrical energy can be stored. The different appliances of electrical energy storage in different industries. The pros and cons of using in electrical energy storage at a company.
"A review of available technologies for seasonal thermal energy storage"	Xu, J. Wang, R.Z.	2014	The different forms in which seasonal thermal energy storage takes place. What the main concept of seasonal thermal energy storage is. The biggest pros of seasonal thermal energy storage.
"Mechanical Energy Storage"	U.S. Department of Energy	2021	An overview of the different forms of mechanical energy storage. Advantages and disadvantages of these different kinds of mechanical energy storage.
"Mechanical Energy Storage"	American Clean Power	2022	An overview of the different forms of mechanical energy storage. A small explanation on the workings of the different kind of mechanical energy storage.
"An overview of thermal energy storage systems"	Alva, G. & Lin, Y. & Fang, G.	2018	How the processes of different thermal energy storage options work.

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