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Introducing New Materials to an Existing Supply Chain
A case study of Vattenfall's black pellets program

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Abstract

To handle the paradox of rising energy demand while still reducing emissions from fossil fuel, Vattenfall will increase the use of biomass. Accordingly, the energy gained from biomass will play an important role in Vattenfall's future energy production.

In 2013 a new type of biomass, called black pellets, will be implemented at Vattenfall. Black pellets is a bulk commodity where logistics costs represent a major share of the products' landed cost. The material will be sourced globally, which implies that innovative transportation corridors will be needed. The similarities and differences between coal and black pellets are mapped, in order to understand how the correlation between the two materials affects the supply chains. This is a task of finding constraints in the supply chain and analysing which trade-offs are necessary, focusing on sea transportation alternatives, inventory levels and the overall costs.

Although coal and black pellets will be used for the same purpose, they do not share the same market mechanisms; hence they should have two separated supply chains. The supply chain of black pellets should be based on a push-pull approach were the main focus should be put on lowering the sea transportation costs and on managing the inventory levels. The findings show that it is the transportation system itself that constrains on the supply chain thus causing the major bottlenecks, rather than the characteristics of black pellets.

Keywords: Supply Chain Management, Inventory Management, Biomass, Black Pellets, Coal, Bulk Material, Dry Bulk Shipping.

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To Emma, a true inspiration

Gothenburg, Sweden, June 2011

Karin Berntsson Hilda Laura Jiménez Chávez

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Abbreviations

3PL	Third Party Logistics
ARA	Amsterdam, Rotterdam, Antwerp
BC	British Columbia
BDI	Baltic Dry Index
BEC	Bio Energy Centre
BP	Black Pellets
Bton	Billion ton
°C	Celsius degrees
CoA	Contract of Afreightment
CHP	Combines Heat and Power Station
CO^2	Carbon dioxide
dwt	Deadweight ton
EC	Eastern Canada
EOQ	Economic Order Quantity
EU	European Union
FOQ	Fixed Order Quantity
GWh	Gigawatt hours
HFO	Heavy fuel oil
HB	Hamburg
k	Kilo
Lb	Liberia
m	Meter
m^3	Cubic meter
MDO	Marine diesel oil
Mton	Million ton
MWh	Megawatt hours
R&D	Research and Development
SC	Supply Chain
SCM	Supply Chain Management
T/C	Time Charter
TAC	Total Annual Costs
Ton	Ton
TWh	Terawatt hours
VET	Vattenfall Energy Trading Department

1. Background and Introduction

This chapter introduces the readers to the main concern of reducing carbon dioxide emissions in the energy market by replacing coal with black pellets. It begins with describing the background and problem discussion that point out the drivers behind this study, followed by the purpose and aim as well as the research questions that motivate this study. Finally the delimitations and the disposition of the thesis are included.

1.1 Background

The global power and heat demand is constantly increasing with coal as its major source (European Commission 2010). At the same time, the importance of reducing emissions and creating sustainable sources of energy is widely stressed, both from end-consumers and from government entities. This paradox creates a challenge for the actors in the energy industry; supplying the increased demand of energy while reducing emissions.

The worldwide energy demand is estimated to rise 1.4 percent per year on average from 2007 till 2035 whereas the increase of renewable supplies for energy accounts for 2.6 percent per year (EIA 2011). In order to secure the energy for around 500 million people within Europe, the European Union has created strategies and policies aligned with the reduction of emission of CO^2 and other noxious substances (European Climate Foundation 2010).

Heat and power production in Europe is largely dominated by fossil fuels, and coal generate one third of the total electricity. The global growth of coal consumption is expected to be 1.6 percent per year from 2007 to 2035, with a major gross increment estimated in 2020 (EIA 2011). The European commission has decided upon targets for the year 2020; greenhouse gas emissions should be reduced by 20 percent, renewable energy sources should represent 20 percent of Europe's final energy consumption and energy efficiency should increase by 20 percent. These targets are called Europe's "2020" targets (European Commission 2010).

Biomass represents 4 percent of the power and heat generated in EU (Johnsson 2011). The consumption of biomass for heat and power is predicted to grow over the coming years. In order to reach the European 2020 targets, actors in the energy market are forced to take action. These efforts require long term strategies for renewable alternatives to be integrated in the energy market as well as innovating technologies of reliable non-fossil fuel as energy sources (European Commission 2010).

The European commission has decided that entities' in EU must pay for the carbon emissions they produce, as a part of the EU Emissions Trading System (European Commission 2011). The fee is based on the carbon content of fossil fuels. In contrast, non-combustion energy sources such wind and hydropower that do not produce carbon dioxide are not convened by the carbon tax (European Commission 2011). As combustion of biomass is classified to be carbon neutral, it remains unaffected by the carbon tax. Consequently, reducing CO^2 emissions is, from the perspective of the energy producing company, not only based on a strive to become less environmentally damaging – it is mainly a subject of reducing the risk exposure from the cost of CO^2 emissions.

By 2020 the power energy gained from biomass would be around 450 terawatt hours (TWh) in Europe, implying that all available biomass from domestic resources must be utilized as well as the feedstock from international allocations. Consequently, biomass imports will play an important role in the future energy supply during the growing competition for energy resources (J. Hansson 2008). Thus, when the locally sourced biomass will not be found in a sufficient amount, innovative pathways will be needed to mobilize the global sourcing of biomass. Due to the long distances of sourcing, sea transportation will be needed and further shipping capacity will be required (Bradley 2009).

This case study is based on Vattenfall, which is a government-owned Swedish company and one of the leading companies in the biomass sector. Vattenfall's long-term target in their own operations is to reduce the CO^2 emissions per unit generated heat and power by 50 percent in 2030 compared to the levels in 1990 (Datamonitor 2010).

To handle the paradox of rising energy demand while still reducing emissions from fossil fuel, Vattenfall will increase both the relative and absolute use of biomass. Accordingly, the energy gained from biomass will play an important role in future energy production for the company.

The market for biomass is far from mature, creating uncertainties and obstacles for both sourcing and trading, compared to the mature coal market, where the price of coal is the major market driver. The market drivers for each respective industry have an impact on the supply chain structure. Introducing a new energy source in the commercial market of producing heat and power, at ordinary coal and gas power plants, will become a challenge in terms of supply chain management.

Torrefied pellets, by Vattenfall named Black pellets (BP), are a new form of biomass that currently does not exist in a commercial scale. The torrefied process breaks the fibbers and removes gases by heating wood chips without oxygen. It is then pelletized in order to simplify transportation. BP is a hydrophobic material, and has higher energy content than wood pellets and wood chips. Due to the similarities to coal it can be co-fired at higher proportions compared to wood pellets and wood chips with only minor modifications in the boiler. Co-firing is when two or more fuels are combusted simultaneously in the same boiler in order to produce heat and power. (European Climate Foundation 2010).

1.2 Description of Problem and Scope

Production of BP in a commercial scale will begin in 2013 for Vattenfall's account. When introduced, BP will be incorporated in the coal-based production of energy and heat. The introduction of co-firing BP with coal will be done gradually between 2013 and 2020. In this up-scaling phase the co-fire share will progressively increase. Implementation of BP over this relatively short time span will put high pressure on the supply chain management (Vattenfall 2011).

Vattenfall seeks to secure continuous supply of biomass by establishing long-term partnerships to produce the material, mainly from three regions: British Columbia, Eastern Canada and Liberia. By investing in the production of BP they will not only manage the supply but also reduce the risk of shortage. The import of biomass will be in the form of BP to a number of coal plants in Germany and in the Netherlands. The long distance between supply and demand requires global transport corridors.

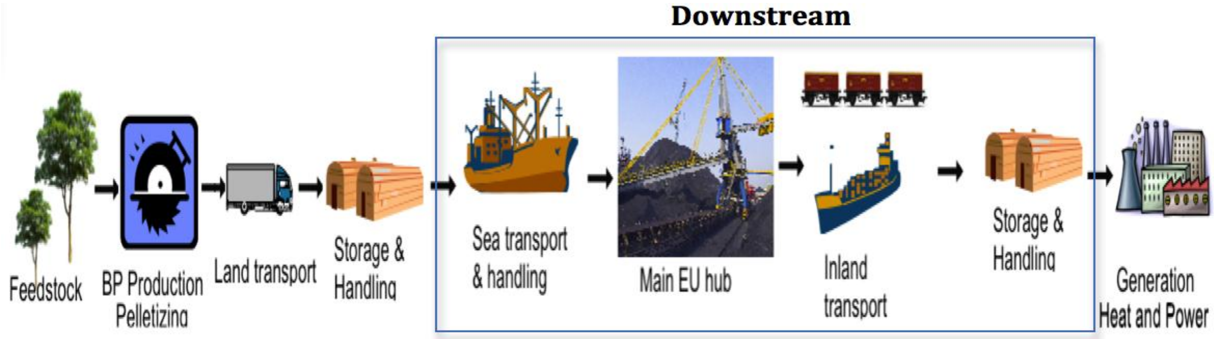

Figure 1 Upstream and Downstream logistics flow of black pellets

Black pellets supply chain can be divided into upstream and downstream logistics. The focus in this thesis is on the downstream logistics. The upstream logistics implicates the flow of material from the forests to the processing plants where the forest material is processed into BP and then transported to the port of destination, and stored until shipment. The downstream logistics begins at the port of origin. The BP is then shipped to one of the European ports, where it is unloaded and stored. It is then put on inland-transportation to the energy plants. At the energy plants the commodity is stored in waiting to be co-fired together with coal (figure 1).

Black pellets is a low-value commodity where logistics costs represents a major share of the products' landed cost, meaning that an increase in transportation cost will have an high impact on the total cost of the product. Global solutions for transport corridors can have different design depending on what variables companies consider being most important. Optimization of the shipping alternatives is a central challenge in this report. This is a task of managing risks and defining what strategies we suggest for Vattenfall and which trade-offs are compromised.

The inland-transportation network in Europe are highly occupied, so to benefit from economies of scale and to utilize equipment, manpower and experience, BP is to be implemented to the existing inland-transportation network of coal.

1.2.1 Purpose and aim

The main purpose with this thesis is to provide an understanding of how implementation of new bulk materials affects an existing supply chain. This is done by study the case of Vattenfall and the scenarios given, where BP is introduced in the existing production of heat and power at Vattenfall's German and Dutch coal plants. Transport corridors will be designed for the downstream logistics of BP from the ports in British Columbia, Eastern Canada and Liberia to the energy plants in Germany and the Netherlands.

Coal and BP do not have the same point of origin; hence these two materials may require two individual transportation corridors. Vattenfall's coal supply chain is mapped in order to analyse the supply chain of BP, to compare these supply chains, and to identify the point of interaction and the possible bottlenecks.

The introduction of BP requires re-planning of strategic decisions regarding logistics. The different co-firing share of BP with coal during the up-scaling phase is another logistical challenge that influences the strategic decisions. These strategic decisions are based on supply chain cost calculations, inventory management calculations as well as a bottleneck analysis to be followed by a discussion of shipping alternatives. Effects of the transport corridor are measured by calculating the overall supply chain cost.

1.2.2 Research question

Aim of the research:

- How to integrate the future supply chain of BP to the existing coal supply chain?

Research questions:

- What strategic solutions are recommended when introducing black pellet from British Columbia, Eastern Canada and Liberia to Vattenfall's German and Dutch coal plants in the current logistic system in Vattenfall, between the years 2013-2020?

- How will these strategies affect the supply chain in terms of the design of transport corridor, focusing on inventory levels, the overall costs and on sea-transportation alternatives?

1.3 Delimitations

This is a study done in cooperation with Vattenfall and the focus will be on their business activities. Since the use of BP for producing heat and power does not yet exist in a commercial scale, scenarios of the future flows are the foundation of this thesis; the figures and assumptions are given in the case study description. There are different studies carried out with estimations of the future producing capacity of biomass, with a huge variation in results. Vattenfall gives the figures for the amount of supply and demand of BP in this thesis.

The focus in this report is put on implementing BP for producing heat and power. There are other types of biomass such as wood chips that are used for this purpose; however, those materials will not be covered in this thesis, as they are not a part of the studied BP program at Vattenfall.

Black pellets can be produced by different technologies, gaining different characteristics. The features use in this report is based on an average type. Calculations on emission reduction that are often mentioned in relation to BP calculation are not included, due to the time limitations of this report and since this will not influence the physical distribution of BP.

The supply chain studied is limited to the downstream logistics, meaning the different flows of material from the ports of origin to the energy plants, named in the case description in Germany and Netherlands. The upstream logistics are not covered in this report; since it is primary a matter of acquisition of supply for Vattenfall's account and since the exact position of the production plant cannot be revealed. Accordingly, we do not have the exact position of the port in British Columbia and Eastern Canada so the distance between the region of sourcing and the ports in Europe is based on an average distance.

Downstream logistics in this report end at the Combined Heat and Power plant (CHP), which means that the final product distribution of heat and power to the end consumer is not covered. Due to the entirely different products, the bulk material that generates heat and power and the intangible products heat and power, has completely different logistic strategies.

Since coal and black pellets will be used for the same purpose the supply chain of coal will be mapped. Thus the focus in this report is on black pellets, and due to co-fidelity a cost comparison between the two materials will not be included.

The Inland-transportation in Europe for BP will use the same logistic network as coal. Focus on optimizing the flow of goods at this stage rather than designing alternative networks, due to the requirements from Vattenfall to utilize manpower, experience and benefit from economies of scale. Alternative costs for using trains instead of barges will therefore not be included.

The objectives are also limited to the physical flow and neither the information flow nor the monetary flow will be covered. The authors strongly believe that the conclusions provided in the paper can be applicable to other industries when implementing new material into an existing supply chain.

1.4 Disposition

The thesis is structured according to figure 2 the disposition will help the reader to follow the logic of the thesis.

- Introduction
  - Chapter 1 Background and Introduction
  - Chapter 2 Research Method
- Case study
  - Chapter 3 Biomass Market
  - Chapter 4 Coal Supply Chain
  - Chapter 5 Case Description
- Theoretical frame work
  - Chapter 6 Supply Chain Managment
  - Chapter 7 Designing Supply chain Network
  - Chapter 8 Dry Bulk Shipping
- Analysis
  - Chapter 11 Supply Chain Analysis
  - Chapter 10 Design of the Transportation Corridor
  - Chapter 11 Bottleneck Analysis
- Conclusion
  - Chapter 12 Conclusion and Further Research
- Appendix
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Figure 2 Thesis Disposition

2. Research Method

The purpose of this chapter is to outline and describe the research method used in this study. The choices of research approach and data collection are motivated. Validation and reliability of the study are discussed in this chapter.

2.1 Research Process

The trend towards more complex environments has generated a need for reliable and relevant information. Research makes knowledge available and endows the researcher with concepts, tools and models to conduct reliable research. The assessment of knowledge when conducting research should be considered, in order to reduce the risk of making incorrect decisions. Thus, the research is defined as a systematic inquiry carried out with the purpose of supplying information that may allow problem solving (Blumberg 2008).

Research processes aim to explain all the procedures made while conducting the research to encourage future duplication. The authors have therefore followed academic standards to guarantee that the data presented is both validated and reliable. High ethical standards are applied; this implies the commitment of the researchers to protect the well-being of the members, organizations, parties, and themselves. In addition, conduction of data is broad enough to permit an adequate analysis of data and a correct selection of the methods chosen. In order to claim objectivity, the findings are presented well-structured and clear (Blumberg 2008).

2.1.1 Research Philosophy

This research is based on the philosophy interpretivism, meaning that we consider the construction of the social world and the subjective meaning people give to it. This philosophy also assumes that the individual composition of the social world and its understanding of it rely in the holistic picture that the researchers makes of this world. Interpretivism suggests that the driving force behind the research always is driven by interests of the researcher and that the researcher is a part of what is observed (Blumberg 2008).

The other research philosophy is called positivism, which is often applied by natural science. The core of this philosophy relies in the existence of the “real truth" and the possibility to understand this reality through the decomposition to its basic elements. The role of the researcher is an independent and objective analyst and the research is value free (Blumberg 2008).

2.1.2 Research Approach

Research approach defines where theory is placed in the research and therefore affecting the outcome of the research. The three main types of research approaches are deduction, induction and a mix of deductive and inductive (Blumberg 2008).

Deductive approach tries to show that a conclusion always follows from a given reason, and if these reasons are true it is provided that the conclusions also are true. The deductive arguments can never be false or true, but they can be valid or invalid. It is a reasoning method used to gain knowledge (Blumberg 2008).

The inductive reasoning is fundamentally different from deductive reasoning. Here, conclusions are drawn from one or more significant facts or evidence and the conclusion explains the fact and the facts support the conclusion so that general assumptions can be gained. The inducting reasoning suggests truth but do not ensure it (Blumberg, 2008).

The research approached used in this thesis is the mix between inductive and deductive, where the idea is to propose new theory. The new theory is applied to an existing one, and through empirical study and corroboration, pre-existing theories can be expanded upon. This approach is suitable for case studies, which is the type of this research (Blumberg 2008).

2.2 Research Types

Studies can be classified in four groups: reporting, descriptive, exploratory and predictive. The basic level of study is the reporting research, mainly used to provide and summarize data and generate statistics. The slight use of inference and limited conclusions are characteristics of this type of study (Blumberg 2008).

2.2.1 Descriptive Study

Descriptive studies focus in the description and definition of topics and analyses of problems or events. This type of study includes analysis of observations in single incidents; also frequencies and distributions of observations are analysed. This kind of research study can involve several variables. The outcome of descriptive studies may generate robust inferences. However, the main disadvantages of this type of study are the incapability of explaining the causes and the interaction between variables of a phenomenon. Descriptive studies are largely used in business research due to the flexibility throughout disciplines (Blumberg 2008).

2.2.2 Exploratory Study

Exploratory study is constructed based in theory. This theory is used in order to answer questions such as “why” and “how”. Exploratory researches not only describe the phenomenon, it also gives an explanation of it. Moreover, relationships between the existing variables are analysed. Theories and hypotheses are used for researchers with the purpose of finding the reasons that cause such a phenomenon (Blumberg 2008).

2.2.3 Predictive Study

Predictive is a type of study grounded in theories and explanations of phenomena. Additionally, inferences are largely used in predictive research. The purpose of this type of studies is to answer questions aiming to improve models used during the research and the opportunity to make forecasts. The prediction's reliability relies not only on the theories - other tools such as models, scenarios and expert surveys are used for these projections. Scenarios are mainly constructed under assumptions, thus predictions are determined by these assumptions. Other important tools for predictive studies are qualitative interviews with experts, which are the basis for the expert surveys. Moreover, implicit theories are integrated in both scenarios and interviews. The result of this type of study is the control, which is the outcome after the explanation and predictions of the phenomenon. Hence, the replication, control and manipulation of the phenomenon to obtain a specific outcome are the main objectives in predictive studies (Blumberg 2008).

2.2.4 Research Type for the Thesis

This research study is based first on descriptive study, where the supply chain of coal is explained as well as the market drivers behind both coal and BP. It continues with an exploratory part where it answers the research question what and how. The authors strive to explain the relationships between the existing variables in the analysis as well as explaining the phenomenon behind them. The purpose aims to explain and predict the outcome for implementing a new material in a current supply chain for the coming years. The decision-making process for choosing strategies when implementing biomass may benefit from the results of this study.

2.3 Case Study

The case study is suitable for different approaches such as exploratory, descriptive and explanatory. A case study is defined as the empirical enquiry used when the focal point is an up-to-date phenomenon within a real context, whose boundaries between phenomenon and context are not well defined and the researchers have a minor influence on the events (Yin 2009).

The case study approach provides procedures to answer questions such as "how" and "why", empowering the researcher to appreciate the contemporary events from a holistic view. However it is less effective to answer other questions such as "what" and "how much". Case study functions attempt not only to describe a single-case, its purpose is also exploratory and it may achieve general answers, thus a sole case can be the foundation for substantial rationalizations and generalizations (Yin 2009).

Numerous sources of evidence within case studies method can be used for collecting data, such as interviews, documents and observations. These sources are used with the aim to assure validity, maintaining the evidence chain and investigating and testing opponent explanations. A case study is not limited to using only qualitative facts; it can also encompass quantitative data or a mix of them (Blumberg 2008).

2.3.1 Multiple Case Study vs. Single Case Study

Whether a single case is needed to answer the research questions or multiple cases are required, depends on the results obtained from them. The use of multiple cases is considered to achieve robust outcome. The assortment of the multiple cases is based on replication logic and not sampling logic such as in the survey inquiries, and the focal notion is the expectation that a similar phenomenon appears if the conditions are identical and vary if the conditions are altered (Yin 2009).

A single case can be used if it provides enough information to answer the research question or in very exceptional circumstances when the case is unique and there is not more than one event available (Yin 2009). Therefore, a single case in this research is justified due to the access to key informants providing sensitive data and valuable information, which is up-to date. Additionally the uniqueness of this case relies in the introduction of BP in a commercial scale, with Vattenfall being one of the first corporations to launch this new material at this scale.

2.3.2 Quantitative vs. Qualitative research

There are two different data gathering methods – quantitative and qualitative research. The objective of quantitative research is to develop mathematical models or hypotheses to explain phenomena. Qualitative data collection uses social factors and develops ways to find and plot processes as opposed to using numbers. Qualitative data collection is often strongly connected to an inductive research approach. Qualitative approach is given by the intention to concentrate on developing a holistic understanding of the subjects. Qualitative research produces information only on the particular cases studied, meaning that general conclusions are only hypotheses, whereas quantitative methods can be used to verify which of such hypotheses are true (Neuman 2011).

According to Blumberg, 2008, quantitative research is preferable for case studies. Due to the data collecting methods chosen, interviews and documentations, the majority of the gained information is non-numerical and is therefore not suitable for quantitative research. Another argument is that this research follows an inductive research approach and strives for a holistic understanding of the research problem.

2.4 Data Collecting

According to Yin, 2008, the case study evidence should be collected from multiple sources. Data collecting tools used in this thesis are mainly documentation and interviews.

2.4.1 Documentation

The documentations used to support our evidence are found in relevant textbooks, formal studies, internal-documents and in journals that are related to our theories. The main strengths of using documentation are the stability and precision they provide, they can be reviewed repeatedly and provide a broad coverage. Reporting and selectivity bias are avoided by systematic literature reviews and an explicit data collective plan. The authors use evidence found in documentation and apply its theory to confirm conclusions (Yin 2009). By using administrative documents given from the internal administration of the company, information not available elsewhere gives deeper knowledge to this case study.

2.4.2 Interviews

Conducting interviews is the prevailing research tool of acquiring the most recent data from the business perspective. The interview will not generate general results about the implementation of new material in the supply chain. Rather, it will provide information and opinions of the participating members regarding the issue at hand (Dawson 2002).

There are three main interviewing techniques that tend to be used in social research. Those are unstructured interviews, structured interviews and semi-structured interview. Semi-structured and in-depth interviews are used here to offer the opportunity to compare the answers, though similar questions were asked. At the same time they were flexible for adjustments on the course of the interview in order to gather the most information as possible. The respondents are chosen to take part in the interviews based on their knowledge and experience in their area of businesses (Dawson, 2002).

Vattenfall is a company consisting of a large number of business departments, working in different areas with different perceptions. In order to gain a wide perspective of the different areas of the company that will be affected by the implementation of BP and to capture the different viewpoints of the departments, the interviews were conducted with experienced persons who are at high organizational levels in their business and function (table 1). In order to gain validity the interviews were conducted at familiar locations for the interviewer and to reduce bias a recorder was used together with notes.

The interviews were conducted in friendly environments at the interviewers' offices, where time pressure were not an issue. The appointments were made in advance with an expert in each area, and the interview started with a brief introduction of this research. The interviewee was introduced as well. Using a semi-structured interview approach, the questions were made based on a prepared questionnaire, leading to new queries and further explanations about related topics. The interviews helped to create a relationship with the interviewees facilitating further communication in order to clarify and to cover new questions by other means such as phone calls or emails.

List of interviewees

Name	Area	Number of Interviews (including telephone interviews)
Assdourian, Sewag	Vattenfall Power Consultant	2
Bratz, Kristian	Gothenburg Chartering, Ship broker	2
Breukelman, Pim	Renewables Business Unit Biomass Development	3
Christensen, Clint	Coal and freight Purchaser	3
Dusan, Stefan	Vattenfall Research and Development	1
Karlsson, Tore	Fuel & Mineral products Purchaser	1
Lundgren, Göran	Renewables Business Unit Biomass	2
Lindén Erik	Teekay Shipping (2nd Engineer)	2
Nilsson, Peter	Renewables Business Unit Biomass Development	3
Padban, Nader	Vattenfall Research and Development	2
Sandberg, Jan	Renewables Business Unit Biomass Operations	1
Ukmar, Andreas	Renewables Business Unit Biomass Operations	1
Westerberg, Erik	Renewables Business Unit Biomass Development	3

Table 1 List of Interviewees

2.5 Validity and Reliability.

The design of the research can be judged in order to secure the validity in the findings. According to Yin 2009, the most common validity tests are: construct validity, internal validity, external validity and reliability. Hence, the constructions of validity depend on identifying accurate measures for the concepts behind this study.

The strategies for securing the validity are based on multiple sources of evidence as well as on creating of a "chain of evidence" during the data-gathering phase. The final strategy to construct validation relies on key informants' revision of the research report (Yin 2009). The construction of validity in this study during the data collection is achieved by using multiples sources of evidence such as interviews with strategic informers, company documents, market statistics and so on. Moreover, the validity in this report has been enhanced by creating a chain of evidence and the review of this report from the key actors in the energy and academic fields.

In the data analysis stage, internal validation aims to establish casual relationships. The results of casual relationships are made by inferences due to the impossibility of direct observation. Yin (2009) pinpoints some tactics such as pattern matching, explanation building, addressing rival explanations and logical models. The internal validity in this paper has been achieved through analysing and comparing patterns, such as the comparison with the existing coal supply chain, by finding the similarities and differences that may affect the introduction of new materials in the existing supply chain and by analysing previous explanations in similar researches. To achieve internal validation we have interviewed participates more than once, to provide the opportunity to add additional data that were missed the first time. Moreover, they have given the chance to read the report to exclude biases.

The main concern for case studies is the external validation; since the findings are mostly analytical generalizations produced from particular a group of results. These findings can be generalized by using theories. However, these theories have to be tested by replicating the findings in other cases in order to obtain the same results. Then, if equivalent results appear, the generalizations may gain validity (Yin 2009). To gain external validity the authors applied well-known theories. Furthermore, the study was presented to researchers and experts in the field during the reference group meeting "Sustainable, Intermodal Supply Systems for Biofuel and Bulk Freight (2011-05-02). The findings presented were agreed upon.

Finally, the reliability test aims to minimize inaccuracies and biases in the investigations. For this purpose the researchers need to document all the procedures used during the case study. These procedures assure the same outcomes and conclusions if the same researcher or other investigators conduct the same case study again (Yin 2009).

Most of the data collection in this study was obtained through interviews, which makes it harder to control the reliability, as opinions from the key informants may change over time. It is a risk that personal opinions are included in the information provided by the respondents. However this is reduced by multiple interviews, recording the conversations and by conducting the interviews without any pressure. The characteristics' of BP is not completely known at this stage, if the development of the material changes into another direction, the outcome will most likely be different if the research were performed again. Hence, the risk of low reliability was taken into consideration but the authors consider that the case study approach was the most adequate the circumstances' in this research field at this time.

3. Biomass Market

The focus of this research is put on the introduction of BP to the coal supply chain. This chapter will provide an introduction to the biomass market. Moreover, the relevant characteristics of BP will be discussed.

3.1 Biomass Introduction

Biomass is a product deriving from living or recently living biological material, i.e. plants or trees. There are several types of potential sources for biomass such as timber, virgin woods, energy crops, forestry products, agricultural residues, food waste, industrial waste and co-products as well as energy crops planted on idle and unoccupied land that constitutes a potential source of biomass for energy purposes (European Climate Foundation 2010). However, it is not probable that biomass will be produced from timber due to its high value. The source of biomass influences the energy density and the characteristics of the end product (BEC 2011).

One of the most important sources of renewable energy for producing heat and power is biomass. The importance of biomass lies in the significant reduction of emissions compared to fossil fuels such as coal; this renewable source reduces carbon dioxide between 55 to 98 percent. It is considered as an extension of sustainable energy alternatives. Biomass is a renewable resource for energy purposes, considered to be carbon neutral in a long term. The photosynthesis is the natural process in which the carbon is naturally captured and stored in the trees, grass, plants and so on. The condition for the carbon dioxide neutral process is the continuous growing of these resources (European Climate Foundation 2010).

During the last decade the trade of solid and liquid biofuels has been growing. Even with obstacles as the recent world economic crisis and the low prices of fossil fuel, biomass and biofuels trade are expected to increase in the next years (D. Bradley 2009). For that reason, it is necessary to develop a sustainable supply chain, bearing in mind the indirect effects such as land-use changes or serious impacts in biodiversity (European Climate Foundation 2010).

According to the European Union, biomass will play an important role in achieving the sustainability levels of the 2020 European target (European Climate Foundation 2010). Some of the applications of biomass are residential heating, industrial heating, electricity production, fuel production etcetera (D. Bradley 2009) The heat and electricity generation in Europe is largely produced from fossil fuels. Hence, replacing fossil fuels with biomass can decrease the climate impact in a relatively short period of time (Vattenfal CSR 2009). The long distance sourcing of biomass will be in the form of pellets due to its favourable characteristics (European Climate Foundation 2010).

Using adequate practices when utilizing biomass is vital, as large-scale use can jeopardize the biodiversity and cause severe alterations in land-use. The competition for land may become a critical issue in the future if energy crops plantations substitute food crops. At the moment the overall capacity of biomass production is sufficient. Nevertheless the probability of shortage may increase during the coming years. These risks have to be taken into account and be managed in order to create a sustainable energy mix (European Climate Foundation 2010).

3.2 Black Pellets

Black pellets (BP) is the umbrella term used by Vattenfall, describing the different materials produced from biomass by using different technologies to be used in co-firing with coal (figure 3). The technical specifications for BP regarding moisture content, ash content, and calorific value, will have different compositions depending mainly on three variables: the feedstock, the refining technology and the requirements at the CHPs (A. Uslu 2006). Black pellets is not a homogeneous fuel from a chemical point of view since it is still biomass (European Climate Foundation 2010). Defining the refining technology to produce BP depends on which fuel is sufficient enough to produce the highest conversion rate needed. It is possible to produce material very similar to coal, however with the drawbacks of an extremely high price (A. Uslu 2006).

Figure 3 Torrifired Pellets (Westerberg E, 2011)

3.2.1 Torrefication

A method used to produce BP is torrefication. There is not yet a standard approach to torrefication of large quantities. Hence, the exact method is not determined.

"*Torrefication is a thermal pre-treatment technology carried out at atmospheric pressure in the absence of oxygen"* (Kleinschmidt 2011).

The process is performed at the temperature of around 200°C to 300°C and produces a solid uniform product with high calorific value and low moisture content. During the torrefication process, 10 percent of the energy value and approximately 30 percent of the weight is lost. The moisture uptake is low varying from 1% to 6%. After torrefication the material is pelletized to ease handling and transportation of the commodity (A. Uslu 2006).

The calorific value, meaning the amount of energy released during combustion, is measured in units of energy per unit of the material, for torrefied pellets is 6 MWh/ton with a bulk density of 750 kg/m3 (equal to 1.33 m3/ton), compared to the calorific value of wood pellets which is under 5MWh/ton and has a bulk density of 600-700 kg/m3. (European Climate Foundation 2010). Black pellets stowage factor is estimated to 1.3 ton per cubic meters (Westerberg E, 2011). The stowage factor is the ratio of weight to stowage space required by a specific cargo. It indicates how many cubic meters one metric ton of a commodity occupies in a hold (Stopford 2009).

Torrefied pellets have several advantages over other biomass materials. It is suitable to be pre-treated with any type of fibrous feedstock material. The cost for long distance transportation is reduced due to the higher density compared to other biomass materials. The hydrophobic characteristic in the torrefied pellets increases the flexibility and reduces costs in transportation, handling, and storage processes (BEC 2011).

4. Coal Supply Chain

In order to implement BP to the current supply chain of coal it is crucial to understand the market drivers and the supply chain strategies for coal at Vattenfall. This is presented in this chapter by mapping the different processes in the supply chain as well as investigating the market drivers in the coal industry. For a better understanding of the empirical data, secondary sources are used as a complement.

4.1 Coal Introduction

The characteristics of hard coal differ somewhat between the regions depending on the composition of the fossils and earth they are mined. Hard coal will be referred to coal in this report. Coal generates one third of the total heat and power in Europe, about 80 million ton of coal were imported during 2010 (EIA 2011). Coal reserves are found globally and at the end of 2009 a total of 826.001 Bton of coal were estimated to be economically minable with the current methods and price levels. In 2009 coal was produced at the levels of 3 4086 Bton of oil equivalent. Coal reserves are mainly found in the Asia/Pacific 31.4%, Europe/Eurasia 33.0%, and North America 29.8% (Nilson 2010).

4.2 Coal Supply Chain Overview

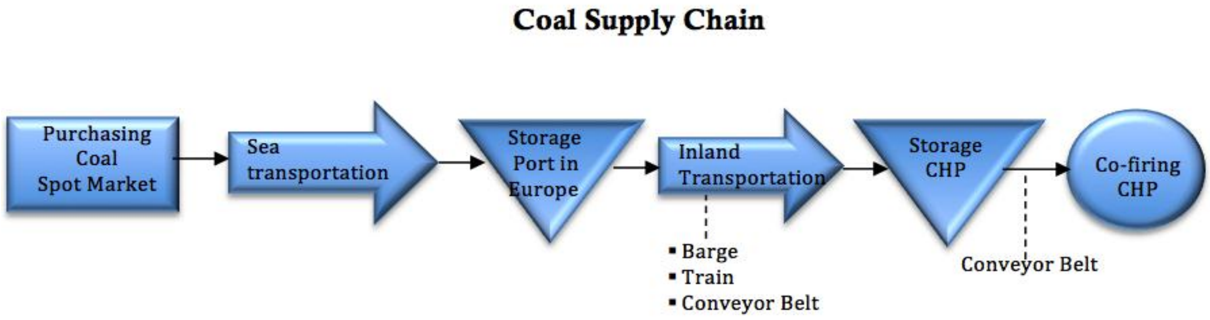


Figure 4 Coal supply chain at Vattenfall

The average supply chain of coal can be described as follows (figure 4). Employees at each CHP makes a coal consumption prognosis, including a coal specification plan of how much of each coal grade that is required, which is given to the Vattenfall Energy Trading department (VET). Each CHP uses more than one quality of coal to gain the most efficient energy output, to the lowest possible cost. It is then up to the trading department to purchase the coal. The coal is bought on the global market, to be delivered by a bulk carrier to a port in Europe. At arrival the coal is discharged and put onto a stockpile at the port. The coal is then put on inland-transportation, to be delivered to a coal terminal or directly to a CHP. It is then kept on storage in piles in the open air, waiting to be used. One characteristic of coal is that it is volatile, meaning that is sometimes has to be compacted at the storage facility, to reduce the risk of self-ignition. The different types of coal are then blended to gain the wanted mix. The final in-house transportation is carried out by conveyor belts, which deliver the coal to the mill to be made into dust. The dust is then sprayed into the burner to generate either heat or power (Assdourian S, 2011).

4.2.1 Coal Purchasing

The coal is bought nine to twelve months before it is shipped. The sea freight is arranged and bought approximately 30 days before it is shipped. Inland logistics are bought and arranged around six months before the coal arrives at the port of unloading. However, the Inland-transportation can be bought a week before discharging the coal at the port, depending on the flexibility required. Since Vattenfall has more than one energy plant they have the possibility to re-position the coal at arrival or during the sea voyage. (Christiansen C, 2011).

The decision of when to purchase coal is based on a number of variables; the costs of coal, the current coal index, market conditions, sea freight rate (chapter 8), the seasonality demand and inventory strategies etc. The American Petroleum Institute provides the coal index, APA1 or APA2 to subscribers. It is a weekly published index which is governed by the coal purchases over the last week (API 2011). The trading department at Vattenfall follows the market trends by scanning the industry market reports and keeps track of all world markets to capture opportunities of buying cheap coal (Christiansen C, 2011).

4.2.1.1 Cost of Coal

The current price for coal is 130 $/ton to Europe (2011-04-21). On top of the price for coal comes the price for CO^2 emissions. The current cost for one tone of CO^2 is about 14 €/ton. This cost has been fluctuating 13 – 20€ during the last years (Westerberg E, 2011). The business model of Vattenfall, with regards to coal and energy, is based on the idea that they will source coal regardless of the market price. As the market price of coal will fluctuate the price for electricity will follow. Although this is not completely true, the trading department tries to get the price of coal as close as possible to the API1 index. At the end what is important is the time spread between the price of raw material and the return profit from the generated heat and power production (Christiansen C, 2010).

4.2.1.2 Coal Index

Indexes are subject to market bargains; the index is not the price it is an idea of what the theoretical value should be. Sometimes one has to pay a premium for the privilege of being allowed to buy coal in a short market, meaning that the price of coal lays over index. The market in Rotterdam, Amsterdam and Antwerp (ARA) is the most liquid market in the world, with a lot of coal going in there. The Danish market on the other hand is not equally liquid, which means that Vattenfall may get a better deal by putting the coal into Denmark (Christiansen C, 2010).

4.2.1.3 Market Conditions

The incentives of throughput are on how good the market is and how the market situation is. The market can be described to be a contangoed market - an upward forward curve. At a contangoed market the current price of coal can be 120 $ but the exportations of the market is that it will hit a 125 $ in the future, meaning that the value of coal is not 120 $ that it is bought for it is actually 125 $. E.g. if the coal arrives in March to be kept on storage for 90 days, the theoretical value of the coal has gone up 7-8 dollars. The opposite market condition to contango is known as backwardation. If it is a backwardation market, Vattenfall will try to delay the delivery of the coal and then burn the coal on storage as fast as possible (Christiansen C, 2010).

4.2.1.4 Seasonality Demand

There are differences in coal demand during the seasons depending on what the CHPs are producing. When the majority of the production is heat the demand will increase during the cold months to decline in the warmer months. When the major product is electricity the demand variation will not be as significant during the year. The demand also differs depending on who is the consumer; are the majority of the customers industries the demand will not have as large variations as if the majority is residences. As well as seasonal variations there are also daily variations – heat demand is stable over the day compared to the demand of electricity that is concentrated to the daytime. Consequently, Vattenfall does not need as much coal during summer, meaning that the logistic patterns differ during the year. The stockpile will increase during the third quarter of the year, to be kept stable during the fourth and the first quarter or the year. In the first quarter, the stockpiles are starting to decrease in size, to keep a low during the summer (Breukelman P, 2011).

4.2.1.5 Inventory Strategies

The right amount of coal to have on storage is difficult to manage. Vattenfall is not acting alone in electricity market in Europe and coal is not the only source for heat and power. The supply goes up or down depending on the competition from other energy sources. Hence, Vattenfall never knows how much coal they will need – what they know is that they have a responsibility to supply the area with heat when it is needed. The risk of not having enough coal to produce energy lays both in lost profits but also in costs of buying electricity from competitors. The costs to go offline with one CHP are enormous, accordingly the importance to support each CHP with the coal they need has a service level of 100, meaning that no interruptions are accepted (Christiansen C, 2011).

The average turn over time for coal depends on what strategies Vattenfall applies. They can have an average turn over time of 3 months or of 9 months; it depends on the trend in the electricity coal market trends. Sometimes VET buy too much coal because they know that they can sell it or if they see a chance that the theoretical value will be greater in the future due supplying the main constrains, but sometimes they go short. The coal market is speculative (Christiansen C, 2011).

VET does not apply any logistical philosophy. They think that supply chain philosophies are killing the logistical performances. Just in time for instance is according to Christiansen to much of a gambling. And as long as the interest rate is low it does not matter, if the interest rate went up to 8-9 % then a just in time strategy would make sense (Christiansen C, 2011).

4.2.4 Sea Transportation

Vattenfall imports coal to approximately seven ports in Europe. The shipping pattern of 2011 shows that is that the majority of the shipments are bought and arranged by the VET departments. The minority of the coal is delivered at the coal supplier’s decision due to a multisource contract – The coal supplier has a contract to supply them with whatever coal they have available, under a certain number of parameters (Christiansen C, 2011).

The stowage factor for coal is 1.16 m^3/ton. This means that one ton of coal occupies 1.16 cubic meters. Bulk density for coal is around 850-925 kg/m^3, with differences between coal grades. A trend within shipping is to reduce the speed in order to reduce the bunker consumption and cost. From the average of 14.5 knots to 13 or 12 knots indicates an additional one to one and a half days for the sea voyage. Vattenfall calculates on a 10-day window, for the ship to arrive (Christiansen C, 2011).

4.2.5 Discharging Coal

The ports in Europe use wheels, cranes with grabs or conveyor belts to unload the vessel. Time to discharge depends on the equipment used and the size of the vessel. It takes around 6 days to unload a Capsize vessel and 4 days to unload a Panamax in ARA. It takes 3 days to unload a short loaded Capesize and Panamax vessel in Hamburg. Supramax and Handysize vessels take 3 days each to unload in ARA as well as in Hamburg. (For shipping terms see chapter 8.1.2 Vessel size.) Handling cost is measured in $ per metric ton, including discharging and putting it on the side of the quay (Christiansen C, 2011).

4.2.6 Storage

According to the VET department there are no central storage facilities for the CHPs in the region of Germany and the Netherlands. Nevertheless, ARA serves as a hub in the transportation network for the CHPs in both Germany and in the Netherlands. It is possible to store coal at Hansa-Port in Hamburg, with a storage capacity of 400 000 ton of coal. Storage is of coal will be possible at Vattenfall´s CHP Wedel in Hamburg with a capacity of 500 000 ton, when this CHP is shot down - this will happen in the nearest future. However Wedel is not equipped with necessary handling equipment, meaning that once the coal arrives at Wedel one can’t get it out of there (Christiansen C, 2011).

Storage fees, at storage areas not owned by Vattenfall, are based on the land area it occupies. However, since the income is higher for unloading and loading coal than at keeping the coal in storage for the company running the storage, they want to have a high turnover, so the price of storage increases after a specific time. The contract for the terminal is negotiated every year (Christiansen C, 2011).

Coal can be stacked relatively high. Introducing a new material will have significant impact on the storage site. For example, at a storage site with 2 commodities stocked in two piles with a capacity of 200000 ton, adding a third pile will reduce the capacity to 150 000 ton and a fourth pile to approximately 80 000 ton, all in total. The more commodities being stored, the less storage place there is. As another example, the Berlin Area currently has 4 stockpiles (graded in to A, B, C, D) which gives approximately a total of 200 000 ton of stock capacity. If you introduce another pile in to the mix you will reduce it to approximately 150 000 ton of total stock capacity (Dusan S, 2011).

4.2.7 Inland Transportation

Vattenfall has yearly contracts with third party logistics providers (3PL) arranging the inland-transportation in Europe. The 3PL is given a 30-40 days window to deliver the coal at the CHP, and it is up to the 3PL to arrange the transportation. Inland-transportation in Europe has fixed flows. Vattenfall can get additional transportation if necessary (Christiansen C, 2011).

During spring, summer and fall most of the coal is transported on barges owned by small players. The European waterways are used to move coal to respectively CHP. The waterways are restricted by depth, length that sets the size of the barges. The barge size depends on the destination. The economy of a barge is based on many variables, depending on the size, the age, the ownership, the position of the barge and the fuel it is using. The price is not as easy to foresee as for a truck or a train, since they are not standardized (Christiansen C, 2011).

An intermodal solution is applied during winter to supply the CHPs in the Berlin area, using both barges and trains. The most cost efficient way to transport coal to Berlin during the winter of 2010-2011, was to use a barge from the OBA-terminal in Amsterdam to Duisburg in Germany, to be reloaded onto a train to the CHPs (Christiansen C, 2011).

The equipment used for the interface between storage sites at the port and barges are conveyor belts. The time to load a barge is about 4 hours, costs for load and discharge is paid in €/ton. Barges are small, meaning that one cannot load as fast as the conveyer belt allows. If the barge is filled with 1000 ton of coal in 30 minutes there will no time to level the coal, making it stay in one corner which most likely will make the barge to flip over (Christiansen C, 2011).

5. Case Description

Vattenfall's goal is to increase the use of biomass by 5 Mton by the year 2020. This chapter will provide a company description of Vattenfall and the outlines of the case study and the scenarios that this case study is based on. The chapter is based on information gained from interviews and company released documents.

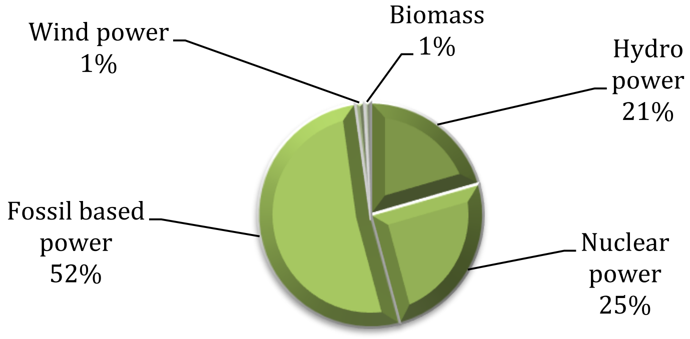
5.1 Vattenfall

Vattenfall is a government owned Swedish company with headquarter in Stockholm and worldwide operations. Vattenfall mainly produces and distributes its core products: electricity, heat and gas, mostly in three markets Sweden, Germany and Netherlands (Vattenfall (c) 2011)

According to Datamonitor 2010, a key competence in Vattenfall operations is the participation in strategic processes throughout the whole value chain, giving a competitive advantage over the players in the energy market. The company operations for industrial and domestic usage comprise: exploitation of resources, trading, energy generation, delivery and sales. Additionally, Vattenfall owns energy resources, for instance lignite mines in Germany (Datamonitor 2010).

5.1.1 Vattenfall and Energy Mix

Vattenfall's business strategy is to have a balanced energy mix and geographic diversification (Datamonitor 2010). In 2010 the Vattenfall's mix of energy sources for electricity generation care illustrated in graph 1 were biomass only accounted for 1.5 TWh. The aggregate electricity generation accounted for 172.5 TWh (Vattenfall's annual report 2010).



Graph 1 Vattenfall mix of energy sources 2010, based on Vattenfall's annual report 2010

The energy mix reduces the sensitivity for price fluctuations and modifications in policies that may impact the company's profits, thus profit from one type of energy can compensate the losses in another. In the same way, the sensitivity for price and modifications in regulations is further reduced by the geographic spread of Vattenfall's operations across Europe. However, the large reliance of the German market may jeopardize the company's position due to the constant fluctuation in the energy prices in this market (Datamonitor 2010).

5.1.2 Biomass and Vattenfall

According to Göran Lundgren, head of the Business Unit of Biomass in Vattenfall, it is important for Vattenfall to reduce CO^2 emissions. The reason is both related to the public relation image as well as a financial risk exposure. CO^2 emissions cost money, the current costs are small in relative terms but the costs are expected to be double in a few years' time, and it is likely to be volatile. Lundgren highlights the considerable diminution on CO^2 emissions in a relatively short period of time by substituting coal with biomass in the heat and CHPs, and consequently the increase of share in the renewable sources in the Vattenfall's energy mix (R&D Magazine 2010).

By 2020 Vattenfall aims to reduce the annual carbon dioxide emissions by 10 Mton. In order to reach this goal it is necessary to swap 4 Mton of coal for 5 Mton of biomass. Additionally, Vattenfall's pursues to be carbon neutral by 2050, and the efforts towards this objective lead to the several strategies in order to increase the use of biomass for heat and power generation (Vattenfall (b) 2011).

Vattenfall's is one of the major purchasers and consumer of biomass, and has more than 30 energy plants of biomass for heat and power, using approximately 3 Mton of biomass per year (Vattenfall (d) 2009). So far, biomass used in the plants comprises various types of fuel with different characteristics, qualities and energy contents, such as wood pellets, wood chips, waste products, forest residues' and so on. The existing coal plants cannot burn this common biomass, without modifications at the CHP. Thus costly investments are required in order to perform the combustion when using these materials (R&D Magazine 2010).

Implementing BP is a way to skip these costly investments hence benefitting from reduced emissions. The local volumes of biomass resources are not sufficient for Vattenfall's production requirements, and there is a need for source biomass from places with a surplus production (R&D Magazine 2010).

5.2 Case Framework

Vattenfall is securing long term supply of BP and are investing in the production capacity of material. Thus, Vattenfall are striving to control a large share of the value chain - from the raw materials in the forest to the generation of power and heat at the European CHPs. Since the upstream logistics are not covered in this report the storage capacity and inland-transportation and the port facilities at the production site, is assumed not to influence or be a subject of problem to the flow of BP (Nilsson P, 2011).

The production speed is in relationship to the set goal of producing 30 TWh per year by 2020. The co-fire rates and the ramp-up are based on this production place. It should be clarified that the figures are based on a roughly estimation and are subject of changes in the future. Cost of BP is not known at this stage but it is estimated to be around 140 €/ton. This figure is subject of changes (Nilsson P, 2011).

5.2.1 Technical Aspects of Black Pellets

The research and development department at Vattenfall are working on black pellet verification in a number of projects to probe the technical effect for co-firing BP in the coal plants. Thus, the production and research development of BP is not part of the Vattenfall process is done by a third party (Dusan S, 2011).

There is not yet a common standard specification for BP. Vattenfall will probably use BP gained from more than one type of technology in their CHPs, due to risk assessment. In this research the characteristics' of the BP used are based from the torrefication method. It is not only the production methods that influence the materials characteristics' the feedstock used when producing BP will also have a great influence. Vattenfall have to balance the quality of the BP that will be used and the requirements at each plant in order to keep the power and heat generation sustainable. The calorific value for Black pellets is set to 6 MWh (Dusan S, 2011).

There will not be any seasonal differences in the production of BP, as the feedstock used for production will be put on stock, to be used when required (Dusan S, 2011). The seasonal demand of BP in the CHPs in Europe is assumed to have a flat base load operation throughout the year (Breukelman P, 2011).

5.2.2 Transportation

There will not be any restrictions when choosing vessel type since it is assumed that BP can use the same vessels as coal, and there will not be any restriction in the inland-transportation. Since the same inland-transportation network can be used there will not be any additional cost per ton in handling or inland-transportation per ton (Dusan S, 2011).

5.2.3 Storage

According to Dusan, BP can be stored outside in the open air. If BP is stored outside, different technologies than used for coal might be needed, like raining systems or ventilation. Black pellets and coal should be separated during storage. If BP is stored in silos can be kept for a longer time, more than a couple of years. It is the storage capacity at each CHP that determine the amount of BP that are possible to store. BP will lose some of its calorific value during the storage outside. The calorific value will decrease differently depending on what technology that is use for production. The angle of repose for BP is different from that of coal, which influences the storage capacity in open piles. The angle of repose for BP it is 38 degrees. The latest values show that BP is not toxic or explosive. The behaviour of BP is under investigation and Vattenfall are working with mapping the biological activity of the material, every characteristic of the material cannot be stated at this point in time (Dusan S, 2011).

5.2.4 Co-firing

Co-firing is when two or more fuels are combusted simultaneously in the same boiler in order to produce heat and power. Conversion efficiency is the ratio between the valuable output from the CHP and the input, in energy terms. With co-firing rates under 50% BP mass the conventions efficiency is equivalent to coal fired CHPs, in the range of <1% boiler efficiency decrease. One can expect, depending on the particle size, volatile matter and moisture content a certain re-distribution of the heat transfer in the boiler. The amount of pellets each plant can co-fire on a daily basis depends on the type of BP that is used, on the targeted co-firing rate and on the investments done at the CHP (Dusan S, 2011).

5.2.5 In-House Logistics

The co-firing process aims to use the same in-house infrastructure at the CHP for BP and coal. BP is assumed to use the same conveyor belts and discharging equipment. At the CHP the material used for producing energy is put through a mill to be made in to dust. The same mills can be used for BP as for coal, when co-firing, although there is an expected capacity reduction of 5 - 25% in throughput. This is also depending on the black pellet type and the co-firing rate, the capacity reduction of 25% is when there is a co-fire share of 50%. Additional investments, such as dust absorption and extra cleaning in the mills might be needed (Dusan S, 2011).

5.2.6 Summary of black Pellets Characteristics'

Since BP will replace coal it is important to know how similar the two materials are. Table 2 illustrate the characteristics' of BP compared to coal.

Summaries of Black Pellets Characteristics'

Same characteristics' as coal	Different characteristics' as coal
• Can be stored outside	• Different Energy Output
• Storage at the same sites	• Different Bulk Density
• No additional dust or smell issues	• No CO^2 emission fees for BP
• Same handling equipment	• Minor investments at CHP
• Same transportation carriers; Vessels, Barges, Train, Conveyor belts etc.	• Need additional ventilation when stored outside
• Same inland-transportation network	
• Same Mill and Burner	
• Hydrophobic	
• Low moisture content	

Table 2 Summary of Black Pellets Characteristics'

5.3 Production of Black Pellets

Vattenfall invest upstream in order to secure continuous feedstock of biomass in the volumes needed at foreseeable low cost. Feedstock availability creates a risk of short supply and a problem of supplying at a reasonable price. To reduce that risk Vattenfall will secure long-term supply of biomass by either contractual arrangement, as in Canada. Alternatively, one can locate production plants where there is cheap forest and where there is no competition, as in Liberia. The overall risk of not securing supplies occurs when there is high competition for biomass and the feedstock price will be un-reasonable (Lundgren G, 2011).

The three regions from which the BP will be sourced are Eastern Canada, British Columbia (Canada) and Liberia (figure 5). The material used to produce BP in Canada is gained from the forest industry, manly from pine threes. Vattenfall will not invest in the logging industry when producing BP, but rather source from the low value material of underutilized wood, or waste wood (ForestTalk.com 2010). Biomass in Liberia is produced by old and unproductive rubber trees. A fully integrated supply chain in biomass is uncommon, but for the Liberia exploitation of resources, Vattenfall will cultivate its own feedstock, coordinate long distance transportation and convert the material in heat and power energy in their own plants (European Climate Foundation 2010).

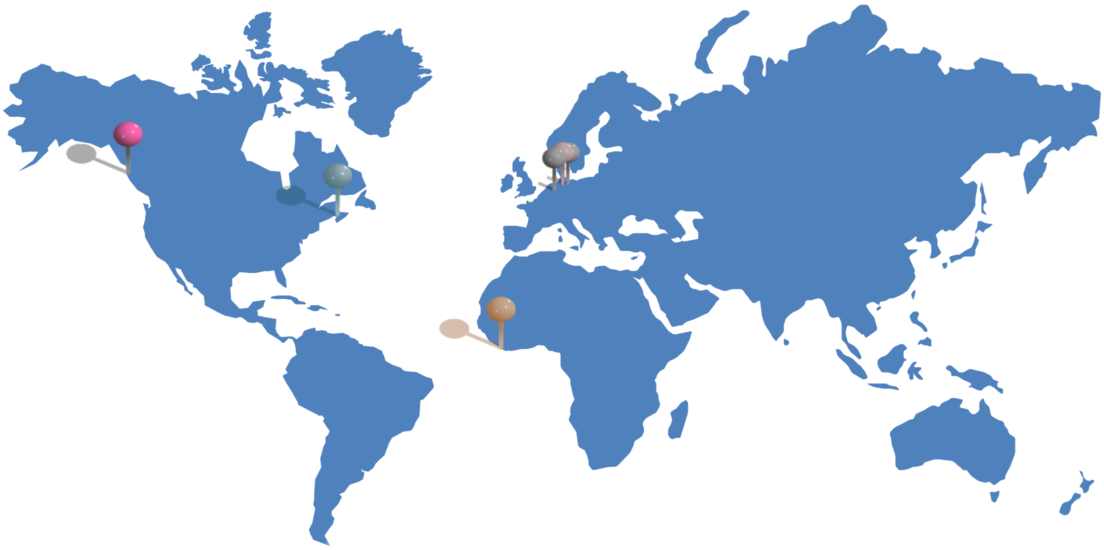


Figure 5 Production sites and port in Europe

5.3.1 Yearly Production of Black Pellets

Production of BP for Vattenfall's account starts in 2012 in Eastern Canada (table 3). Production of BP from British Columbia will start 2014. At Vattenfall's biomass production plant in Liberia the production of BP from unusable rubber threes will start in 2018 with 500 000 ton Nilsson P, 2011).

Yearly Production of Black Pellets (k ton)

Production plant /year	2012	2013	2014	2015	2016	2017	2018	2019	2020
Eastern Canada	250	500	500	500	750	1000	1250	1500	2000
British Columbia	-	-	250	500	750	1000	1250	1500	2000
Liberia	-	-	-	-	-	-	500	1000	1000

Table 3 Yearly Production of BP

5.4 Energy plants in Europe

The CHPs that will use BP are situated in Germany and in the Netherlands. The German CHPs are Tiefstack, Moorburg, Reuter West, Reuter and Moabit. The Dutch CHPs are Hemweg and Buggenum, see figure 6 for their locations.

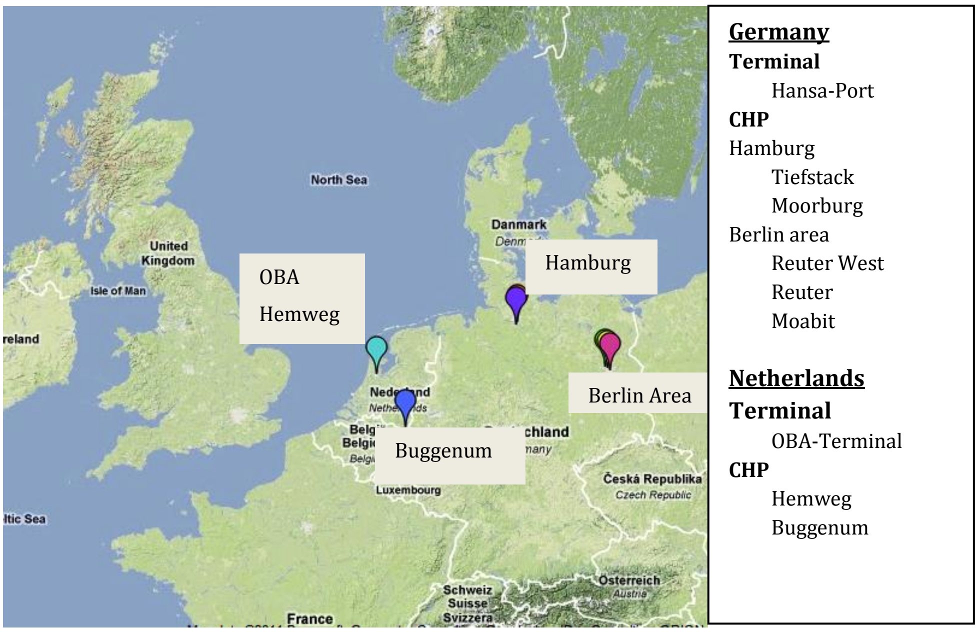


Figure 6 Map of the European CHP and of the two terminals (Built in www.g3imagebuilder.net)

5.4.1 Berlin Area

Reuter West is situated in Berlin, close to the CHP Reuter and Moabit. It has the highest production capacity of the CHPs in the area, with the annual electricity generation of 2570 GWH, it supplies 514 000 households with electricity. Currently, only hard coal is used as fuel. The CHP consumed 7.7 Mton of coal in 2010. Moabit has an annual electricity generation of 355 GWH and 490 GWH of heat production. The main energy source is coal. The CHP supplies approximately 71 000 households with electricity. The third CHP owned by Vattenfall in the Berlin Area is Reuter, supplying 120 000 households with electricity. The main energy source is hard coal. In 2011, the annual electricity production was 600 GWH and 930 GWH heat (Vattenfall Powerplant 2011).

The three CHPs are supplied with coal from either Hamburg or ARA. Barges or smaller riverboats mainly deliver the fuel, with maximum capacity of 1500 dwt. The voyage from Hamburg to Berlin takes about 2-3 days (Padban N, 2011).

Due to regulations of noise and the need of personnel, discharging is set to working days Mondays to Saturdays 07.00 – 18.00. The station for discharging barges consists of two different cranes with grabbers, which lift up the coal onto the conveyor belt. It takes approximately 2 hours to unload a barge. The area is not protected from rain or snowfall. The railway transport of the fuel is done in special wagons, which are emptied by opening the wagon sidewall. Discharging a train does not require any crane; instead the load is dropped into a bunker situated directly below the train. From there it is delivered to the conveyor belts. Storage capacity at the site is 220 000 ton. Currently, there are around 3-4 piles of coal at the storage site (Padban N, 2011).

5.4.2 Hamburg Area

The Tiefstack facility caters for almost half of the Hamburg district's heating and electricity needs, as it supplies 270 000 households. The average annual electricity generation is around 1350 GWH and 1200 GWH heating production (Vattenfall Powerplant 2011).

Coal to Tiefstack is currently unloaded at Hansa-port in Hamburg or at Wedel and then transported to the plant by barges. The transportation takes approximately 2 hours, loading and unloading time of one barge takes 4h, and the capacity of the barges is around 2500dwt. At the CPH there are two coal silos, with a capacity of 40 000 ton each. The existing coal conveyor belt has a capacity of 230 - 300 ton/hour and it is not possible to add much more capacity (Padban N, 2011).

5.4.2.1 Moorburg

This power plant is under construction, and scheduled to be completed in 2012. Moorburg is designed to supply 2300000 households with electricity, equal to 11.5 TWh, which meets about 90% of Hamburg's electricity needs. It is designed to be one of the world's most modern and efficient CHPs producing both electricity heat (Vattenfall Powerplant 2011).

The station will have its own port access, with a depth in port to 10.5 m. The station is situated at the river Elbe close to Hamburg. The storage capacity at the plant will be 2 x 160000 ton silos, with a maximum of 3 grades per silo (Padban N, 2011).

5.4.3 The CHP in the Netherlands

The Hemweg CHP is situated near to the coast in the Netherlands. It consists of two units, Hemweg 7 and Hemweg 8. The main fuels are gas and coal. The electricity generated in 2010 was 4991 GWh, supplying 998 200 households with electricity (Vattenfall Powerplant 2011).

Buggenum is also known as the Willem-Alexander Power Plant. It is a coal gasification plant modified to allow co-firing of biomass and the station has a unique construction for carbon capture and storage (CCS). The source of energy is hard coal and the annual electricity generation 2010 was 1 468 GWh, supplying 293 600 households with electricity (Vattenfall Powerplant 2011).

Currently, coal is shipped to the two stations at the port of IJmuiden. The largest vessel size that can enter is a Capesize vessels of 150 000 dwt. The port has a maximum depth of 13.75 meters, and to enter the port the vessels have to lighten 1/3 of the commodity onto barges. From the port, the cargo is shipped by barges to OBA-terminal, owned by 3PL. The total storage capacity is 2 Mton, of which 300-400,000 ton is for Vattenfall's account (Breukelman P, 2011).

Inland-transportation of coal from OBA to Hemweg is done by conveyor belts directly from the stockpile to Hemweg. The maximum storage capacity at Hemweg is 50,000 ton and the average amount of coal on stock is 30,000 ton (Breukelman P, 2011).

The coal is shipped from OBA to Buggenum by barges. The capacity of a barge is around 2,400 – 3,200 dwt for BP. Two barges are pulled simultaneously by one tugboat. The voyage from OBA to Buggenum is about 20 hours. Only one barge can be discharged per day. The storage capacity at Buggenum is 30 000 ton. It is possible to have one barge with coal and one with BP in principle, although it might be difficult with the balance (Breukelman P, 2011).

6. Supply Chain Management

This chapter will cover the logistical theories that will support the analysis and the conclusions. It will provide an insight into the theoretical background of this thesis, which is necessary for in the multifaceted analysis.

6.1 Supply Chain Definitions

Supply chain (SC) involves all the activities related to the movement and transformations of goods, from the extraction of resources to the end consumer (Ballou 2004). Supply chains do not only embody the physical flow of goods; it also encompasses capital flow, and the conception and deployment of intellectual resources (Ayers 2000).

The flows of goods in organizations are commonly described with the resemblance of the stream in a river, if the flow is near to the origin of source is called upstream, and contrarily, if this flow is near to the final consumer is known as downstream, illustrated in figure 7 (Harrison 2005).

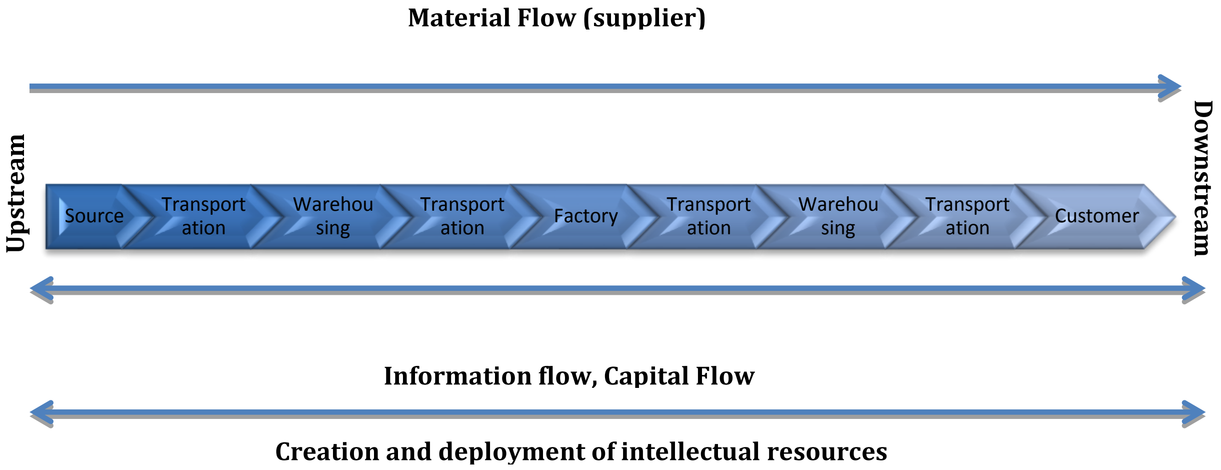


Figure 7 Supply Chain Scheme (Based in the Network Context, Harrison 2005 page. 11 & Ballou 2004 page 3)

A Supply Chain is commonly described as the set of actors involved in the transformation of resources into finished products, adding value in each phase of the flow in order to satisfy the final costumer (Harrison 2005). An ordinary supply chain encompasses several suppliers that deliver products and material to numerous locations and to several warehouses, and then to different factories that in their turn pass them on to several retailers for the distribution to the final consumers (Simchi-Levi 2009).

6.1.1 Supply Chain Management

The Supply Chain Management (SCM) goes beyond the company boundaries, thus through collaborations and coordination between actors in the SC achieving a sustainable and competitive advantage (Ballou 2004). Supply Chain Management is defined as a group of approaches with the aim to integrate providers, producers, warehouses and sellers in an efficient way. The purpose of SCM is the distribution of goods at the correct amounts, in the correct locations, at the right time and simultaneously to reduce costs across the SC whilst achieving the required service level (Simchi-Levi 2009).

6.1.2 Logistics and Integrated Logistics

"Logistics management is the part of supply chain management that plans, implements and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin to the point of consumption in order to meet the customers' requirements" (CSCMP 2010).

Goods and services has value when they can be reached by the customer at the specific time in the right place for its consumption, therefore logistics concerns value creation for consumers, providers and stakeholders (Ballou 2004).

The logistics management is primarily responsible for performing the planning, organizing and controlling of activities in the SC with the purpose of achieving company objectives. In the planning stage, the goals in the firm are established. During the organizing stage, resources are collected and positioned in order to achieve the goals set during the planning stage. At the end, the control stage will measure the outcome and it will try to ensure the alignment with the company goals. If they are not aligned, proper corrective measures must be implemented (Ballou 2004).

6.1.2.1 Planning Logistic Activities

The planning relies in the understanding of the company goals, and it should take into consideration concepts and principles as well as tools with the intention to choose between several procedures. The planning includes inventory strategy, transport strategies and location strategies (Ballou 2004).

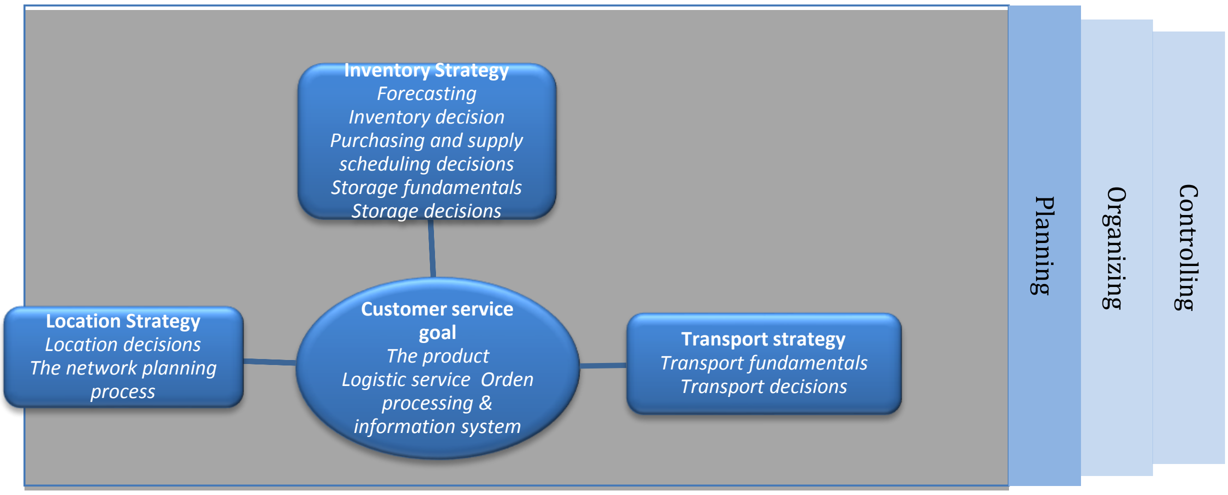


Figure 8 Based on the Principal Activities of Logistics/ SCM (Ballou, 2004 page 29)

Figure 8 illustrates the principal activities of logistics. Planning is related to questions such as what, when and how for the levels of activities, namely strategic level, tactical and operational levels (Ballou 2004). Strategic level activities outline the entire network, which involves long-term decisions that has impact on the company. These decisions include product design, activities that should be outsourced, partner selection, number, size and capacity of productions plants and storage sites and their locations, as well decisions regarding the flow of goods across the supply chain. The Tactical level involves decisions with mid-term impact in the company, which includes inventories, purchasing and manufacturing decisions, and transportation strategies and so on. Lastly, the operational level is a short-term decision with every day resolutions, for instance scheduling, routing, lead-times decisions and so on (Simchi-Levi 2009).

The major task for planning is to achieve goals for these levels with different time perspectives. Therefore, planning involves angles for each level, for instance in the data collection, a short term planning is often accurate and reliable, contrary to the plan in a long term, which most likely is incomplete and vague (Ballou 2004).

A logistics plan or strategy influences the system design through the major areas such as customer service, locations, transport, and inventories decisions. Logistics planning is basically needed when a company is in a start-up phase or when a new product is introduced in the current manufacturing line. Moreover, if the supply chain network already exists, the key areas have to be analysed in order to decide whether it requires modification or should continue with the normal operations. For instance, the changes in a current supply chain that may require a re-planning process are: alterations in the customer patterns, changes in competition, policies or service goals, as well as changes in the product characteristics and the need to reduce logistics cost, when these costs represent a high share of the total cost. Another factor for re-planning strategies in a current system is the changes in the transportation rates, due to its importance in the total logistics costs (Ballou 2004).

6.1.2.2 New Product in the Supply Chain

Introduction of a new product may impact the supply chain and can become threat or an opportunity to the company. The supply chain management methods will not motivate the customer response, but SCM might influence the success or failure of the product. A suitable layout of the supply chain will improve the efficient and cost-effective introduction of the product to the supply chain (Ayers 2000).

According to Simchi-Levi et al, the group of events related with new product integration is called Supply Chain Development, including the design of products, correlated sourcing selections, manufacturing plans, competences and understandings that need to be developed within the company. The development chain involves decisions about the product characteristics, what activities that can be outsourced, what strategic partnerships to enter, and the level of involvement in the sourcing process. The production stage is the point of intersection between the Supply Chain and the development chain; therefore all decisions made within the development chain will influence the current supply chain. Moreover this junction will also have an impact in the product design (Simchi–Levi 2009).

There are different types of new products introduced in the supply chain. Some products are easily introduced with common procedures and with slight variations, contrasting with other types of new products that will require development of new technologies, new manufacturing processes, changes in inventory policies, different partnerships and even a need to design an additional supply chain (Ayers 2000). Simchi-Levi points out that the common deviation from aligned product designs and supply chain strategies can be explained by the presence of different managers aiming at different goals across the activities in the Supply Chain Development and current Supply Chain.

6.1.2.3 Aligning strategies

Strategies need to be aligned through the entire supply chain that often rivals with other priorities through different stages (Harrison 2005). The effectiveness of the supply chain strategies relies in the alignment towards the corporate and business unit goals. Some benefits obtained from aligning strategies are the increment on revenues, reduction in cost and it may enhance competitive advantage. The SC strategy stresses the contributions in reaching the corporate and business unit targets. The main outcomes of aligned strategies are the accomplishment of those targets and the creation of a sustainable value in the SC. Moreover, this alignment pursues to define the suitable competences in the supply chain with the intention of satisfying customer demands while cost goals are reached. Hence, alignment of strategies will contribute to the company and business success by reaching goals and keeping a sustainable growth (Gattorna 2003).

Four main components can be identified in the supply chain with aligned strategies. The first component is the business alignment reached by utilizing the corporative vision and the company guiding principles. The next component submits that market alignment can be achieved with the effective market segmentation. The third component is the strategic response, which is defined by providing appropriate service offers to the final customer, sustained via cost service analysis. The last component pinpoints the relation between the design of the strategic response and the way that the supply chain should work (Gattorna 2003).

6.2 Inventory Management

This chapter describes the pros and cons of holding inventory, different types of inventories, inventory approaches as well as the purpose of having inventories and main trade-offs. Additionally the Economic Order Model (EOQ) is explained as well as the variation of EOQ taking into account inventories in transit.

Inventory management is a fundamental process in the Supply chain management. Through the whole supply chain, variations and uncertainties are constantly appearing. In order to cope with these irregularities and ambiguities, companies use inventories, which are vital parts for the daily operations in a company. The main objective of inventories is to ensure an effective and efficient operation in the company and to increase flexibility. Inventories also mitigate shortages of products, controlling lead-times and delays as well as decreases insufficient assortment of products. According to Simchi-Levi aggregated demand is always more accurate than single forecasted demand. Inventory management largely influences the strategies of the raw material sourcing processes and the deliveries of finished products, thus influencing key performance areas such as finance and production (Gattorna 2003).

Inventories are usually associated with increasing costs however correct inventory management may help to reduce total costs by compensating inventory-carrying cost. Holding inventories allows larger levels of goods for longer periods of time at the manufacturing plants, boosting economies of scale in the production. Firstly, holding large inventories can be balanced with discounts in the price when purchase large amounts of materials for production. Besides, if the price is expected to increase in the future, holding extra inventories may be justified. Variations in demand are another reason for holding inventories, thus uncertainties caused for these variations will influence the total cost and service level in the supply chain. Moreover, keeping inventories will help to reduce unexpected contingences that impacts lead-times and service level. Nevertheless, holding inventories may trigger unfavourable results in the supply chain such as unnecessary increase in the capital costs (Ballou 2004).

6.2.1 Types of Inventories

Inventories can be found in different stages of the supply chain and in several forms. Efficiency in the manufacturing plants, correct distribution and inventory control can decrease total cost and increase the service level. Therefore defining inventory control instruments for each type of inventory can result in huge benefits (Simchi-Levi 2009).

There are several types of inventories whose principal concept can be defined as: Raw materials are all type off material used for manufacture purposes; those materials include manufacture materials from other providers. Working-in-process materials are materials taken from storage site and they start the manufacture process in productions plants, the amount of these materials will vary between industries and it relies on the type of process utilized at the plant. Finished products are those materials that are ready to be consumed by the costumers; therefore the company holds these inventories in order to keep the availability for consumption (Gattorna 2003).

Inventories kept for speculative reasons have to be included in the total inventories costs. Some material such as coal and gold are raw material bought for speculation, based on the price rather than quantities for production requirements. Additionally, dead inventories are those materials that are lost, stolen or obsolete. Thus, security and safety measures have to be taken into account in order to avoid these dead inventories (Ballou 2004).

6.2.1.1 Safety Stock

Safety stock is another type of inventory, which is an extra inventory with the purpose of mitigating the variations in the supply chain. These inventories are calculated in order to address the average demand and lead-time (Ballou 2004).

To determine the level of safety stock there are different methods developed. Manually estimated safety stocks are based on experience, it considers tide-up capital, storage cost and the consequences if shortage occurs. These methods are most often used due to pragmatic reasons. The drawbacks of this method are that it is difficult to reflect variability in demand, meaning that constant revision is needed. In the next method safety stock is based as a percentage of lead-time demand. In this method the safety stock can be changed following the in demand for the product. In the last method safety stock is calculated based on service level required and on the acceptable disruptions in the flow of the material. This approach is the most accurate as it considers the variations in demand (Jonsson 2008).

6.2.2 Seasonality in Inventories

It is not always easy to set the amount of inventory required. Companies frequently have to meet seasonality changes in demand or supply or both. Those variations have an impact on the quantity of inventories required and therefore on the supply chain. The seasonality can appear within the company networks (inbound) and/or outside the company (outbound). The seasonality can be identified for example in the purchasing stage; this is because the products are available or required for one season. The characteristics of the products can also have seasonality pattern such as perishable products or harvested goods. Due to the weather condition, weather represents a factor that contributes to the seasonality on inventories. The seasonality in demand largely influences the level of inventories required, for instance in companies with high peaks in demand it is probably more productive to accumulate inventories and utilize smaller manufacturing plants. Hence, the trade-off between manufacturing cost and inventory cost has to be analysed as well as the capacity and the warehousing space (Bardi 2003).

6.3 Inventory Purpose

One of the main objectives in the Inventory Management is keep the balance between service level and costs. Inventory management seeks to meet the desired service level by reducing inventory in each stage of customer service. Service level is defined as the probability to fulfil customer requirements with the current stock (Ballou 2004).

$$\text{Service Level} = 1 - \frac{\text{Estimated number of unit out of stock annually}}{\text{Total demand}}$$

Service level rates is a number between 0 to 1, which usually is a specific rate so Inventory Management will be responsible of control the estimated amount per year of units out of stock, for instance the service level equal to 0.95 means the probability of 5 percent to not find the required goods on stock (Ballou 2004).

Bardi et al., identify four factors for enhance service level. Firstly, the improvement in responsiveness levels in process and management orders systems. Secondly, improve information systems and the strategic management of them. Thirdly, ensure capability and reliability of the transportation network. Lastly, achieve availability on inventories in the position and moment they are needed (Bardi 2003).

6.4 Inventory Approaches

Different approaches are found in the Inventory Management, therefore the selection relies in defining if the type of demand is either dependant or independent, if there are single or multiple facilities and to select between push and pull philosophies. Demand is independent when it is not associated with the production of other products, thus the independent demand is not in function of other goods. For example, demand for heat and power is not dependent on the demand for coal or BP. Contrary, dependent demand will rely in the demand of other goods, thus the raw materials demand will depend on the manufacturing products demand. Therefore, forecasting demand for independent goods will be more important than dependent goods (Bardi 2003).

6.4.1 Push or Pull Approach

Usually supply chains are categorized in Push or Pull approach. Firstly, push systems are based on long-term forecasts, where the forecast of manufacturing is made from the orders received. The push system is a proactive approach that uses inventory replenishment to forecast demand. However this approach reacts slowly to the market changes and patterns in demand, moreover it can lead to excessive inventory levels, products obsolescence and undesirable service levels. Secondly, systems based on Pull approach responds to specific orders, called a reactive system, and relies on customer demand. This approach improves response to changes in demand and can reduce inventory levels, lead-times and increase flexibility in the system. This approach is not useful for long lead-times and can increase the difficulty for economies of scale. Pull approach also increases the risk of the bullwhip effect. For some supply chains a pull-push system can be more suitable, which is a mix between these approaches and may take advantages from both. The crossing point between them is located at some point in the supply chain, and is called Push-Pull Boundary (Bardi 2003 & Simchi-Levi 2009).

6.5 Inventory Cost and Trade-off

Inventory cost is usually an important factor in the total cost through the supply chain. Changes in inventory levels will have an impact on service levels, thus this trade-off has to be analysed with the purpose of finding an optimal point between them (Bardi 2003). Additionally, in order to set an appropriate inventory policy, conflicts between the order costs, carrying cost and out of stock orders have to be analysed as well (Ballou 2004). This trade-off is clarified in figure 9.

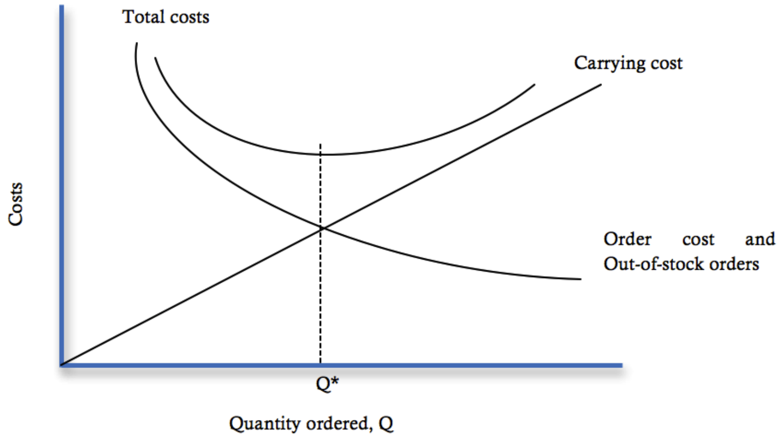


Figure 9 Trade-off of inventory cost with order quantity (Ballou 2004)

The inventory costs in this graph are described as follows: order costs for replenishment of goods are those related to the processing, transmitting, handling and purchasing orders. This type of costs is largely related to order quantity decisions. Order costs involves price of the product, manufacturing costs, processing costs through the internal departments within the company such as accounting and purchasing, costs for transmitting orders to suppliers, transportation costs and handling and processing order costs at the point of reception. Some order costs may vary depending of the size of the order, e.g. variation in transportation, manufacturing and handling costs. For other type of orders these costs are fixed (Ballou 2004).

Inventory carrying costs are associated costs for holding and storing goods for a period of time. The first cost related to inventory carrying is space cost, which involves storing goods in a warehouse. The charge can be for example by volume, however if the company owns the warehouse, other costs have to be added. Space costs are not included in the inventories-in-transit costs. Another type is capital cost, which is driven by the capital invested in inventory and often accounts for approximately 80 percent of the whole inventory cost. Inventory service costs are the types of cost related to taxes and insurance, however taxes are generally only a small fraction of the total inventory cost. The last type is the cost for risks, which are related to loss, damage, deterioration, obsolesce and so on (Ballou 2004).

The out-of-stock costs are generated when an order is not fulfilled after it is placed. These can be represented in two different ways – loss of sales and backorder cost. Loss of sales costs is associated with the loss of profits for the failure in possible sales, in case the customer decides to cancel an order that cannot be fulfilled. This could have several consequences, such as alterations in future sales if the costumer replaces the current supplier. Backorder costs represent the costs for unfulfilled orders, in case the order is postponed rather than cancelled. Such delays can create additional costs in processing, handling and transport activities. Both loss of sales and backorder costs are difficult to measure due to the likelihood of lost sales in the future (Ballou 2004).

6.6 Fixed Order Quantity (FOQ)

The aim of the Fixed Order Quantity model is to fix the quantity of goods for each order or reorder of goods placed. The quantity will depend on the cost of the products, the characteristics of demand, order cost and inventory carrying costs. Generally, when a minimum stock level is established, this will regulate when to place a new order of the fixed quantity. This is known as a reorder point. When the amount of goods gets to a certain level, the fixed order quantity is ordered, thus the level of goods will decide the net order, which is known as Economic Reorder Quantity, ERQ. The amount ordered is also a function of the lead-time to arrival at the desired destination, as well as the demand of goods (Bardi 2003).

6.7 Economic Order Model (EOQ)

The model proposed by Ford Harris is the economic lot size model, also called economic order model. This basic model aims to find the optimum order point with the objective to reduce purchasing and carrying costs, and at the same time addressing the needed demand. This model focuses on avoiding shortage of goods while also taking into account the trade-off between order cost and storage cost (Simchi-Levi 2009).

The assumptions in this model are: The demand is assumed to be known and constant and completely satisfied. Lead-time is assumed to be known and constant. The price is constant and the order quantity and time do not have influence on it. For every time that and order is placed, the fixed cost will be incurred. There is no inventory in transit in the system. Only one item is in the system, and if there is more than one, they will not interact with each other. Inventory carrying costs are accumulated per unit per day held in the inventory. The horizon for inventory planning is considered to be endless. There is no restriction in capital availability (Simchi-Levi 2009 & Bardi 2003).

This model has been criticized for its simplicity and remoteness from reality. However this model is justified when the variation in demand is small and it could be better than using a more complex and costly model. Another argument for this model is that it is suitable when data availability is restricted. Lastly, the EOQ model can be justified if the variability in the input data will not represent major changes in the calculated outcomes (Bardi 2003).

- R= annual demand for period (units)
- Q= quantity ordered lot size (units)
- A= cost placing an order or set up cost (€ per order)
- V= value or cost of one unit of inventory (€ per unit)

- W= carrying cost per € value of inventory per year (% of product value)
- LT= Lead-time (in days)
- S= VW= storage cost per unit value per year

Simple EOQ formula:

Total annual cost (TAC) = $\mathrm{TAC}=\frac{1}{2}\mathrm{QS}+\mathrm{A}\frac{\mathrm{R}}{\mathrm{Q}}$ Where:

Quantity Order Lot Size = $\mathrm{Q}=\sqrt{\frac{2\mathrm{RA}}{\mathrm{S}}}$ Inventory Carry Costs = $\frac{1}{2}\mathrm{QS}$ Order Costs= $\mathrm{A}\frac{\mathrm{R}}{\mathrm{Q}}$

6.7.1 Adjusted EOQ for Bulk Transportations

When dealing with bulk commodities, were the transportation freight are discounted for larger shipments and where the order quantity already are set by the transportation mode used, the EOQ formula must be adjusted. The decision maker has to consider how the lower transportation costs that are gained with large order quantities affect the total costs. In the adjusted formula, Q is set by the capacity of the transportation mode. Moreover, the costs of having inventory in transit are also included. Since, the companies are having ownership of the commodity while it is under transportation, there are always costs attached to holding inventory. If different transportation modes have different transit times, the trade-off between transportation costs and in-transit inventory carrying costs should be examined (Bardi 2003).

Adjusted TAC for Volume transportation rates = Inventory carrying cost + Order cost + In-transit inventory carrying cost + Transportation cost

It is calculated with the following formula:

$\mathrm{TAC}=\frac{1}{2}\mathrm{QS}+\mathrm{A}\frac{\mathrm{R}}{\mathrm{Q}}+\frac{\mathrm{t_m}}{\mathrm{t}}\mathrm{QVW}$ + Transportation cost

In-Transit Inventory Carrying Cost = $\frac{\mathrm{t_m}}{\mathrm{t}}\mathrm{QVW}$

- W= cost of carrying inventory in transit
- V= value/ unit of inventory
- t= order cycle time
- t_m= Inventory transit time
- M= Average number of transit unit of inventory in transit

Where M is calculated as:

Then $M=\frac{t_m}{t}Q$

$$t(days\ in\ cycle)=\frac{360\ (days\ in\ year)}{R/_{Q}\ \ (cycles\ per\ year)}$$

6.8 Tied Up Capital

Assets in a company can be divided into fixed and current assets. When companies invest capital is tied up, affecting the company's cash flow and solvency. Commodity that is under transportation is a part of the company's current assets, meaning that they influence the total capital that is tied up in the company. In order to measure the logistical performance it is important to calculate the amount of material that is tied up. It can be measured as; capital tied up in absolute figures: inventory turnover rates or average throughput time at a current storage point. Inventory turnover rate is useful when one is comparing tied up capital between different stock points. It refers to how many times per year average stock are turned over, meaning that it state the value of the flow of materials during a certain time period in relation to the average capital during the same time period (Jonsson 2008).

An increase amount of capital is successively tied up in the material as it is transported from production site to end customer. Hence, products tie up more capital downstream the supply chain. From this point of view the material should be stored as far upstream as possible. In the same way, lead-time reduction has a greater impact on tied up capital the further downstream and closer to final consumption than lead-time reduction earlier in the flow (Jonsson 2008).

According to Jonsson (2008) tied-up capital is calculated with the following formulas:

Average Stock= (lead time*number of pieces) /the ships leaves every X days

Average tied-up capital=Average stock*Value of the product (at this stage)

7. Designing Supply Chain Network

This chapter points out the main elements for the design of a supply chain network, covering the correlation between variables and the possible trade-offs and bottleneck theory.

7.1 Network Design

Planning the design of Supply chain encompasses providers, manufacturing plants, storage sites, distribution centres, raw materials, inventory in process and holding inventories. The planning of supply chain networks aims to optimize inventory levels, transportation and manufacturing processes. As a part of the design planning, inventories will be positioned and managed in order to meet the supply and demand, even during uncertain conditions. Finally, the task of planning will be to secure the adequate use of goods through selection of adequate source of resources (Simchi-Levi 2009).

Simchi Levi et al, 2009 highlight three steps for planning the supply chain network. These steps are the network design, the inventory positioning and the resource allocations. Designing a supply chain network is a crucial decision in the SC with the purpose to create a competitive advantage and boost profits by using drivers such as transportation, inventory, facilities, information, sourcing, and pricing. The design of supply chain networks comprises the performance in manufacturing plants, and the allocation, capacity and demand for each plant and warehouse. The objective of a supply chain network is to maximize profits whilst achieving a desired service level, connected with customer demand and level of response. Inventory positioning involves the identification and selection of storage sites and its capacity and production volume in order to decrease holding inventories. All these actions must be in accordance with the inventory management strategies. The last step in the design planning is the resource allocation, which is related to decisions of product design and sourcing strategies, the optimal capacity of each manufacturing plant and so forth (Simchi-Levi 2009).

7.1.1 Transportation Design

The transportation network design will have a direct impact on the performance of the supply chain and is directly linked with the variables of cost and responsiveness level of the customer. Therefore, the correct design will lead to cost reduction while increasing the responsiveness level (Chopra 2007).

The selection of transport mode can be categorized as either strategic planning or an operational decision. If it is a long-term selection of transport mode it would be considered strategic, however if the transport mode is just for a single shipment then an operational decision is required (Shapiro 2001).

Any transportation decision has to take cost of transportation and inventory into account, striving to reach the optimization point between them. For instance, if the transportation cost is reduced the lead-time is generally long and the quantity of goods requested for this mode is usually higher. Consequently inventory levels will rise as well as costs. On the other hand, expensive transportation modes usually reduce lead-times and permit smaller quantities of goods, thus reducing inventory costs that may offset the transportation costs. Goods with high value-weight ratio are frequently shipped in faster modes, thus reducing inventory, which is important for the total cost. On the other hand, for goods with a low value-weight ratio low cost transport modes are usually chosen, when the transportation cost is important for the supply chain (Chopra 2007).

Hence, the design of a transportation network goes beyond the selection of transportation by cost alone. It should consider the carrying inventories, cycle and safety inventories. The performance of the supply chain will rely on these decisions. Moreover calculations of cost are necessary in order to design an effective transportation network (Chopra 2007).

7.1.2 Transportation Costs

The transportation cost is in function to the distance between the point of origin and the point of destination (Simchi-Levi 2009). According to Shapiro J (2001) the transportation cost can be classified on flow cost (direct costs) and transportation resourced cost (indirect costs).

Flow costs are those directly related to the movement of goods across the supply chain, for example contract cost, distance and freight rates. The costs related to the management of the flows are known as transportation resource cost. These are the indirect costs of transportation, for instance investments, routing system, spare parts, legal costs and so on. The volume of goods and the type of transport mode determines flow costs. The product characteristics will also influence the cost, as costs often depend on volume and weight. A product's requirements for special handling and equipment will also influence the costs. Transportation resource costs add value to activities, but after a cost analysis this indirect cost can be avoided if the company contracts a third-party carrier, which can increase the benefits and reduce cost (Shapiro 2001).

Transportation costs are associated with the number of warehouses, thus a greater number of warehouses will increase the distance and therefore the cost of transportation. However, the warehouses are usually near to the next destination of the goods, which means that the distance and consequently the costs may be reduced. For instance, goods with high value, low demand

and/or uncertain demand can decrease transportation cost by using a central warehouse, conversely the transportation cost can decrease if several warehouses are used, if the goods stocked are low-value with high demand and certainty in the demand (Simchi-Levi 2007).

7.1.3 Warehouse Capacity

The flows per year and the amount of inventory cannot indicate the space needed at the storage site, as space required is in proportion to the peaks of inventory rather than flows of goods per year or average inventory (figure 10). Therefore the inventory ratio has to be calculated, which is the sales per year divided by the average inventory level. The annual cost is calculated by multiplying the average inventory level by inventory holding cost (Simchi-Levi 2007).

Inventory turnover ratio: $\lambda = \frac{\text{Annual sales}}{\text{Average Inventory Level}}$

An important aspect in the design of the supply chain network is the warehouse capacity. The warehouse capacity can be calculated by the annual flow of material divided by the inventory turnover ratio, and the result is the average inventory level (figure 10). The capacity should consider the spaces for access, handling, picking, sorting, and so on, so the required space is multiplied by the factor (>1). This factor varies according to the particular purposes and gives a more real calculation of space needed for storing the goods. Commonly a factor=3 is used for practical reasons (Simchi-Levi 2009).

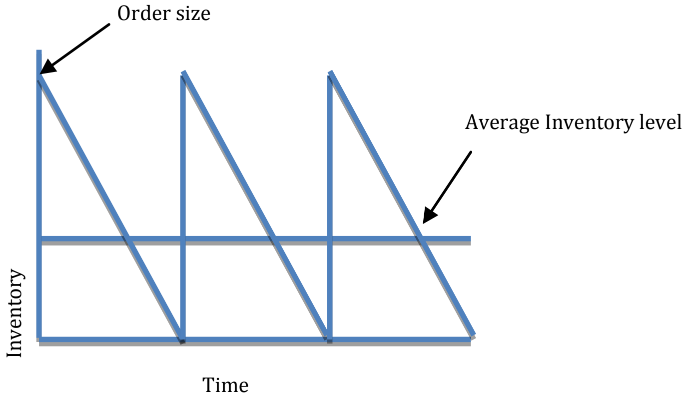


Figure 10 Inventory Level Capacity as a function of Time (Simchi-Levi et al, 2009, page 89)

In order to select suitable allocation for warehouses, some requirements that have to be taken into account are geographical conditions, infrastructure, raw material availability, labour availability and cost, tax regulations, local industries, public interest, environmental regulations and so on. In addition to these requirements, internal conditions have to be included such as service level and future demand (Simchi-Levi 2009).

7.1.4 Weight-Bulk Ratio

Weight-bulk ratio is a measure related to transportation and storage costs. High weight-bulk ratio products are those with high density, which lead to lower costs in transportation and storage. Contrarily, products with low-bulk ratio and therefore with low density, tend to increase costs in transportation and storage due to utilization being reached before the weight capacity is used up. This means that the cost for handling will increase since it is based on the products' weight (Ballou 2004).

7. 2 Bottlenecks

Bottlenecks or constraints define the operational capacity in a supply chain system. Bottlenecks are functions, departments or resources in a network, where the capacity requirements are larger than or equivalent to the actual capacity. Hence, identifying bottlenecks is an important activity in order to control the correct flow in the supply chain (Lawrence 2000).

The theory of constraints (TOC) is an improvement philosophy proposed by Eliyahu Goldratts, mainly focused on the enhancement of processes. This philosophy pinpoints the existence of at least one weakest link in any supply chain, and that a weakest link can be localized and strengthened (Lawrence 2000). This theory assumes that processes are developed in order to achieve their full capability, however the consequences for interdependences or relationships between processes are not considered in this assumption (Dettmer 1997). The optimal flow with the available recourses in a system is achieved by focusing on the whole chain rather than each process (Lawrence 2000).

7. 2.1 Constraints Classification

The types of constraints that can be identified in a system are: physical constraints, policy constraints and paradigm constraints. Physical constraints are also classified in internal and external, the capacity of one resource in the company or a third party capacity are examples of internal and external constraints respectively. The rules established by managers can limit the capacity in a process within the system. These policies or managerial constraints are difficult to localize, for instance efforts toward optimizing a single process can constraint the system. The last type of constraints is paradigm constraints, related to routines or interpretations that can lead to other types of constraints (Lawrence 2009).

8. Dry Bulk Shipping

This chapter describes the multifaceted shipping market and its drivers. Further, it covers both the physical characteristics' of a vessel as well as the different variables that influences business decisions regarding shipping alternatives.

8.1 Background to Dry Bulk Shipping

Hard coal is a heavy and relatively cheap commodity that historically has not been shipped great distances. Today it is the second largest commodity shipped by dry bulk carriers. Seaborne coal trade services two markets; either the coal used as fuel for power generation, or as raw material for steel making (Stopford 2007). Transporting materials in bulk is by far the cheapest way to allocate large quantities over vast distances. It is achieved by using large vessels, as the freight cost is divided between the ton carried and the costs do not rise in proportion to the size of the vessel. Accordingly, cost savings depend on the size of the vessel and also on the distance of the voyage (Stopford 2007).

Transportation networks for bulk commodities commonly include sea transportation connected with inland-transportation at both the port of origin and port of destination. The transportation network also includes storage sites that serve as a buffer for the time elapsed between the arrival and dispatch of commodities. For each stage, handling activities increase the accumulated transportation costs. Naturally the transport requirements vary depending on the characteristics of the commodity and type of industry. The aim of the transportation system is to reduce cost and enhance efficiency regardless of the type of commodity (Stopford 2009).

According to Stopford there are four principles to consider when designing a sea transportation network for bulk material. Firstly, use bigger ships to gain economies of scale. Secondly, reduce the number of handling operations. Thirdly, improve the handling of cargo. Finally, minimize the amount of stock in the system. Hence, the challenge of designing a transportation network is to address trade-offs while reducing capital cost. Additionally, the objectives are not always focused on achieving the lowest transportation costs, as other variables can be prioritized (Stopford 2009).

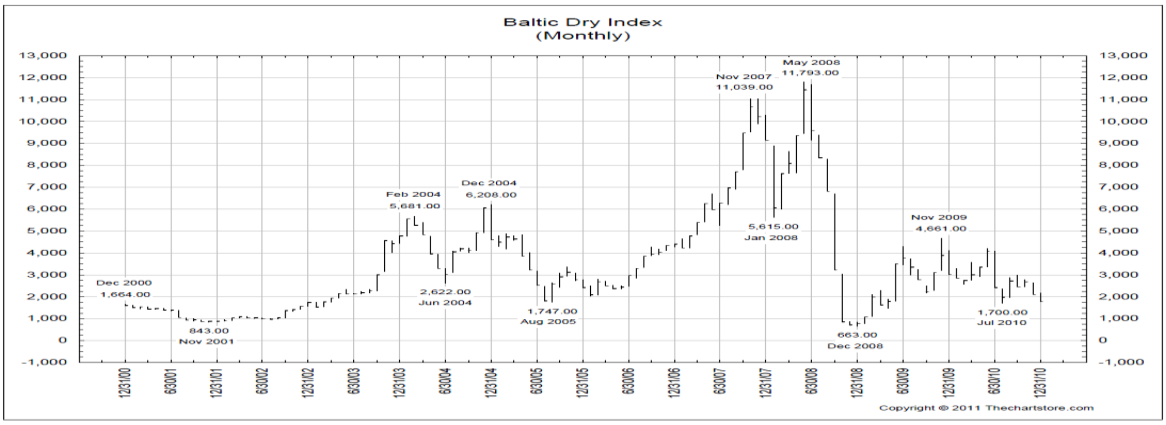
8.2 Shipping market

The shipping market is complex and influenced by many variables. It is basically the balance between supply and demand of goods and available tonnage that sets the freight rate. Since it is a highly competitive market the freight rates can change significantly over a short period of time. As a result of the latest regression, the world´s shipping demand decreased and the market became highly volatile. World coal consumption was at an all-time low in 2009, the weakest year since 1999 (BP 2010). When demand dropped, there was an overcapacity of vessels, and many ship owners had to lay up vessels. At the same time new bulk vessels entered the market, adding even more freight-capacity, consequently affecting the freight rates (D. Bradley 2009). The pressure on the freight rates continues as more newly built ships keep entering the market. This is caused by ship owners having ordered vessels during the bull market preceding the global regression, and the fact that it takes one to three years to build a vessel, without even considering the waiting time for a slot at a yard (Nilson 2010). As presented, the rapid changes on the demand side are in contrast to the less adjustable supply side. According to Stopford 2007, it is economical relationships like these that create the short time freight cycles in the shipping market. In additional to short time cycles there are also seasonal cycles and long term cycles.

The seasonal cycles are a result of the seasonal patterns of demand of transportation over the year. These vary depending on the type of commodity and corresponding vessel type. For example, demand for coal peaks during the cold winter periods in the northern hemisphere when heat and power are in demand, followed by a decrease during the warmer summer seasons (Stopford 2009).

The longer-term cycle is driven by technology, when newly developed ships enter the market making shipping more efficient and stimulating investments in the market, such as the introduction of containerized goods (Stopford 2009).

A freight cycle lasts on average 8 years. The cycles are highly irregular and unpredictable. It consists of four stages; the though stage, the recovery stage, the market peak and the market collapse. The Baltic Dry Index (BDI) provides an index that tracks the worldwide international shipping prices of various dry bulk commodities, issued daily by the Baltic Exchange. Graph 2 illustrates the freight rate index between 2000 and 2010. During this timeframe the four stages of the freight cycle are exemplified. The first stage between 2000 and 2003 it is referred to as the tough stage, followed by the recovery stage during 2003 to 2004, with minor peaks in this period, which is demonstrating the uncertainty in the cycles. The real peak occurred in 2007 and 2008 with a historically high freight index. The market collapsed in 2008 and the freight index dropped by 3000 units in a few months (The Baltic Exchange 2011).



Graph 2 Baltic Dry Index, 2001-2010 (The Baltic Exchange 2011)

8.2.1 Bulk Carriers

Bulk commodities are shipped in large quantities without any packaging. Bulk carriers are designed to be simple and cost efficient. The key features are cubic capacity, cargo handling gear and access to the holds. The vessel size for bulk carriers is divided into four main categories; Handysize, Supramax, Panamax and Capesize. The main measurements of a bulk carrier are the length of the vessel, depth of the hull, the vessels deadweight, which is the maximum capacity of the ton the vessel, can carry and finally the grain capacity that is restricting the volume to be fitted in the vessels holes. (Stopford 2007). Bulk carriers are designed with wide holes to gain a high grain capacity.

8.2.2 Vessel Size

The relationship between freight price and ship size, can be referred to as economic of scale. It is the price per transported unit that is of most importance for the charterer. Stopford defines the annual cost per dwt of a ship as the sum of operating costs, voyage costs, cargo-handling costs and capital costs incurred in a year divided by the size of the vessel. The relationship between the variables is interesting as operating, voyage and capital costs are not in proportion to the size of the vessel. Hence, using a bigger ship reduces the unit cost per ton (Stopford 2009).

Three main trade-offs determine the size of the vessel; economies of scale, parcel size and the port facilities and restrictions. Parcel size is determined by the maximum available quantity of the commodity, which is accepted by the receiver. It is also affected by investment size, storage capacity and supply chain strategies. Port facilities such as cargo handling equipment, storage capacity etc. influence the vessel size, however not to the same extent as restrictions such as port draught, capacity of fairways and canals, and length of the quays. The vessel sizes used in this report are showed in table 4 (Stopford 2007).

Vessel sizes			
Vessel classification	**Average dwt.**	**Draft (m)**	**Cubic m3/ton**
Handysize	20 000 – 35 000	8.7 - 10.7	1.25
Supramax	40 000 - 60 000	11.4 - 12.1	1.30
Panamax	60 000 - 100 000	13.4 - 13.7	1.16
Capesize	100 000 > 300 000	16.6 -18.9	1.0

Table 4 Vessel sizes (Stopford 2009)

8.2.3 Market Segments

Since the different vessel sizes serve different needs in the shipping market, they also represent different market segments. Handy size vessels work on markets where high flexibility and smaller parcel size is demanded, and with a shallow draft they are able to enter smaller ports. Handysize vessels have emerged as the port infrastructure development has led to larger ports. Handysize also serves the flexible market as they are equipped with handling gear and have relatively shallow draft. Larger Supramax vessels are also called Supramax. Panamax vessels are designed to be as large as possible but still fit the Panama channel. Hence they are operating the markets of coal, grain and bauxite. The largest vessel type for dry bulk is Capesize vessels, used for coal and iron ore transportation. In 2006, Capesize vessels were are only able to access around 19 percent of the world's ports (Stopford 2007).

8.2.4 Shipping costs

The freight prices for each segment are not comparable, since it serves different markets. For example, the time charter average price for a Capesize was $ 9298 compared to the smaller vessel size Panamax with a higher average time charter price of $ 16747, the 21 of March 2011 (BIMCO 2011).

The shipping cycles described above illustrate the variables that set the freight price. It also describes the problematic part of trying to forecast future freight rates. Even if the variables are known, the correlation between them and how they are influencing each other are impossible to predict. There are a number of methods to forecast the future freight rates such as Opinion survey, Trend analysis, Mathematical models and Probability analysis. Ship and freight broking houses work full time with analysing the market and trying to predict the future freight prices (Stopford 2009).

The Baltic Forward Assessments (BFA) provides historical data of the average time charter prices for dry bulk vessels that has been traded worldwide. Capesize average during the last ten years is 49548 $/day, and the T/C for Panamax is 25753 $/day. Data for Supramax vessels covers only the last six years, the average time charter price during these years are 28432 $/day.

Handysize have been followed for five years providing a five year time charter average of 21332 $/day (The Baltic Exchange (a) 2001-2011).

8.2.4.1 Forward Freight Agreements – FFA

One way to manage freight rate risk is to use freight derivatives, such as FFA, which is a financial instrument for trading specified time charter and voyage charter rates for forward positions. The derivatives are settled against various freight rate indexes published by the Baltic Exchange. FFAs are 'over the counter' products made on a principal-to-principal basis, meaning that they are flexible and not traded on any exchange. The process is similar to arranging a normal time charter, with the exception of physical commitment involved. It starts with a cargo owner that wishes to hedge the freight rate on his cargo. He then proceeds to a broker that outlines the contract terms and conditions; the agreed route, the contract month, the quantity required, the time period and the contract rate at which differences will be settled. Settlement is between the charterer and the ship owner in cash within five days following the settlement date. When the contract expires, and the settlement price is higher than the agreed price the ship owner will compensate the charterer with the differences, and vice versa. The main problem with freight derivate is that it not only attracts key players such as charterers and ship owners, but also speculators (ICS 2008; Stopford 2009). The 28 of April 2011, the current time charter average FFAs for the four dry bulk vessel sizes were:

Capesize	14300 $/day
Panamax	13581 $/day
Supramax	13175 $/day
Handy size	10519 $/day (The Baltic Exchange (a) 2001-2011)

8.2.5 Bunker price

Bunker fuel accounts for a quarter or a third of vessel operating costs. Higher crude oil prices result in higher bunker fuel prices, which will be reflected in higher transportation costs. So, for low value commodity such as dry bulk, a high bunker price will force down the margins for dry bulk operator (Stopford 2009).

For shipping activities, bunker fuel is a considerable expense. A sea going vessel uses two types of fuel, heavy fuel oil (HFO) for propulsion and marine diesel oil (MDO) for the auxiliary engines to produce electricity for domestic purposes and cargo handling equipment (Nilson 2010). Within emission-controlled areas, ECA, vessels have to burn HFO containing max 1 % sulphur, compared to unregulated HFO typically containing 4 %. There is price difference between the two types that varies but is un-proportional. Sulphur and particle emission controls apply to all fuels, including MDO, though different levels apply. The current regulation for MDO is 0,1% sulphur. Figure 11 shows the ECA in the Baltic and Nordic Sea. (IMO 2011).

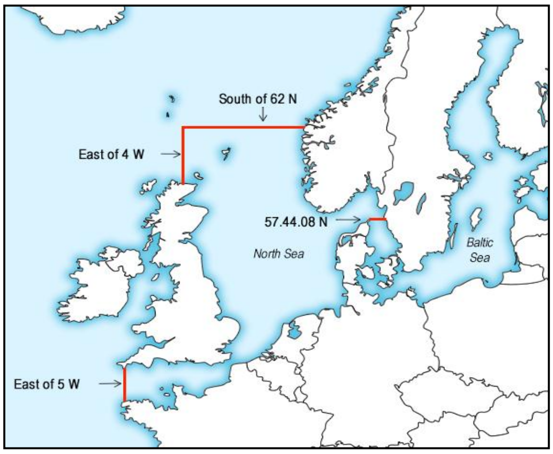
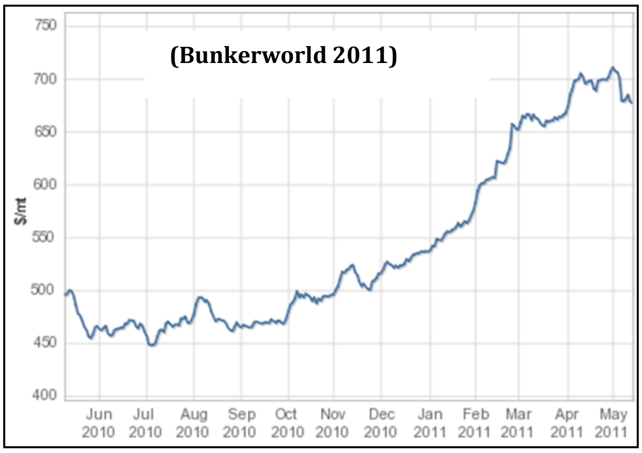


Figure 11 ECAs Baltic and Northern Sea (Sustainable Shipping 2009)



Graph 3 HFO prices June 2010-May 2011 (Bunkerworld 2011)

The world merchant fleet is responsible for around ten percent of the world's total oil consumption. In the last 5 years, bunker prices have risen considerably. Graph 3 illustrates the increased bunker prices between June 2010 and May 2011. The current bunker price in Rotterdam is HFO 620 USD, MDO 933 USD, and for Low sulphur HFO 650 USD (16 May, 2011 (BIMCO 2011)).

The speed of the vessel impacts the fuel consumption. Every vessel has its own so called optimal speed. Reducing the speed by 20 % will reduce the bunker consumption by 50 %. A Supramax vessel's main engine consumes approximately 40 ton of HFO per day. Thus, by reducing the speed with 20 % the vessel can reduce the bunker consumption by 20 tons (Ronen 1982).

The size of the vessel also has an impact on the fuel consumption, see table 5. A dry bulk carrier has a relative low consumption of MDO, around 3-5 ton per day independently on the size of the vessel (Linden E, 2011).

Bunker consumption per vessel size (ton/day)

Vessel size	HFO loaded, ton/day	HFO ballast ton/day	MDO berth ton/day
Handysize	25	20	4 – 5
Supramax	30	25	4 – 5
Panamax	35	30	4 – 5
Capesize	60	50	4 – 5

Table 5 Bunker consumption per vessel size in ton/day (Linden E, 2011)

8.2.6 Imbalance in the Global Trade

Due to the general imbalance in the flow of goods when shipping bulk commodities, the freight rate for one voyage includes the back haul trip. This is caused by most flows of goods being unidirectional, i.e. without return flows. (D. Bradley 2009). The freight rates will only be affected if there are predictable and significant flows of goods in both directions. Accordingly, if the carriers have an opportunity to charter the vessel both directions, the freight price per voyage will decrease (Stopford 2007). For example, South America is called the front haul market as a consequence of the great amount of bulk exports and low imports of bulk to this region. When contracting a transport from South America the shipper has to pay for the round trip to position the vessel. For bulk vessels this normally means ballasting from Asia or Europe. Accordingly, the freight rate for transportation from the region is high and importing to the region is low. On the other hand, between West Africa, that has higher import of bulk than export, and East South America the distance is only 5 days, leaving the possibility to allocate vessels from West Africa instead of Asia (BIMCO 2011).

8.2.7 Shipping Contracts and Risks

There are four main charter party contract types: Voyage charter, Contract of Afreightment (COA), Time charter (T/C) and Bare Boat charter (B/B). The four contracts carry different risk distributions and the costs are appointed differently between the ship owner and the charterer. The shipping risk is the investment in the vessel including the return capital, which is not returned over the period of ownership. It is the market freight cycles that represent the largest shipping risk (Stopford 2007).

8.2.7.1 Voyage Charter

The voyage charter is a contract for transportation of a specific cargo for a single voyage, to be loaded in one or more ports and discharged at one or more ports. The payment of the transportation is either paid as a lump sum, or more commonly in pro rata meaning the quantity of the cargo carried, such as price per ton (ICS 2008). Voyage charters are agreed on in an open spot market, meaning that each voyage is purchased at current market levels. The freight covers the actual transport including an agreed time for loading and discharging, called lay time. Lay time is the time spent in port, or waiting for berth. If the vessel is delayed, e.g. due to slow cargo operations, berth availability etc. the charterer is subject to reimburse the ship owner pay demurrage to the ship owner. If the ship is released early the owner is subject to pay dispatch to the charterer. The cost for both demurrage and dispatch is related to the freight rate, if there is a low freight rate demurrage/dispatch will be low and vice versa. Under this contract the ship owner pays for all the costs, such as bunkers, berth dues etc., except shore-side activities. He is also responsible for managing and running the ship. The ship owner takes both the operational and shipping market risk, thus he loses if there is no cargo available or if the ship breaks down. This is a contact that is contracted on the spot market. A voyage charter contract requires little knowledge about shipping from the shipper's side, as he is only responsible for getting a low freight based on the spot market price. (Stopford 2009).

8.2.7.2 Contract of Afreightment

In a Contract of Afreightment (COA) the ship owner agrees to carry a given quantity of cargo between named ports for an agreed series of voyages at a fixed price (ICS 2008). The agreed voyage charter terms are negotiated, such as time frame, parcel size, number of voyages per year and so on. Thus, the negotiation problem lies in specifying volume and timing in advance, since this might be hard to predict for the shipper. This requires good shipping knowledge from the shipper's side. (Stopford 2007). To fulfil the agreement, the carrier may employ his own vessels or charter-in from others, allowing improved fleet utilization and route planning. The ship owner is securing employment, this is especially important if he considers that the freight rates are about to fall. For the shipper it is a contract that secures transportation over a longer time, and he will obtain a financial advantage if the freight price will rise. The contract is often a modified voyage charter with a similar risk assortment (ICS 2008).

8.2.7.3 Time Charter

In a Time Charter contract the vessel is hired for a specific period. The time charter differs from the voyage charter as the charterer resumes control of the operational destination of the vessel. The charterer pays for bunker, port charges, and other cost related to the cargo, hence holding the operational risk, meaning that the shipper is required to have a comparatively good shipping knowledge. The ship owner is left to pay for the management of the ship such as crewing, insurance and maintenance, he has also holds the risk to lose revenue if the ship breaks down. Time charters are often contracted between three months up to five years, often with several optional periods. The hire is set to a daily rate to be paid with set intervals, normally this will be monthly or fortnightly (ICS 2008; Stopford 2009) .

8.2.7.4 Bareboat Charter

Under a bareboat charter contract the charter takes full operational control over the vessel over a long term contract, most often five to ten years. These contracts are suitable if the cargo owner is relatively sure about the future flows of goods, or if he intends to employ the vessel on the spot market (Stopford 2007). The charterer manages the vessel and holds both the management and the operational risk as the ship owner only is the investor. The ship owner is rewarded with a reduced responsibility and risks, in return the hire payment is lower (ICS 2008).

8.2.8 Buy a Vessel

Another solution is to acquire a vessel to operate and manage for one's own needs of transportation and thereby cut of the ship owner from the equation. The main question to be asked is if there is a sufficient amount of cargo flows in the future, and whether the sea transportation cost will be reduced compared to the alternatives (Stopford 2009). The risk allocation of owning a vessel and running it for one's own transportation need, not only includes the operational and management risk but also investment risk. Not to mention the social responsibility obtained if an accident occurs that could possibly cause environmental disasters. It is also necessary to have good knowledge about the shipping market as well as knowledge on how to manage a crew, vessel and other related issues. Although, it is possible to let a third party run the management of the vessel to spread the responsibilities (Stopford 2009).

The two options of acquiring a vessel is either to build a new vessel, or buying one on the second hand market. Acquiring a vessel is one of the most capital-intensive assets; the reason is the high price in combination with the relevant short lifetime. A new build vessel has a more capital invested compared to an old vessel. On the other hand the daily costs are reduced, that is costs that are related to maintenance and reparations as well as cost of bunker fuel since the engines are usually more efficient than older models. The capital cost does not only depend on the age of the vessel it is also depending on at what time the vessel was bought. However, the age of the vessel does not have a significantly influence on the freight rate. For instance, in time charter contracts the operational cost will increase with the age of the vessel potentially raising the freight cost. Under a voyages charter the difference in freight rate for old and new vessels is negligible, due to the fact that it is the charter that is paying for the operational cost. Older vessels on the other hand may produce more emissions than new vessels, influencing the possible emission rights at the company buying the transportation (Nilson 2010).

The price of a second hand vessel follows the freight market fluctuations, it requires good knowledge of the market in order to buy and sell a vessel at the right moment. The difference in price of a vessel can vary tremendously over a short period of time. Under extreme conditions in the market, last seen in 2008, the price of a vessel can increase fivefold over a short period of time, and then drop down to be as low as the scrap price, in the course of a month. The ability to survive over bull markets depends on the cost the shipping company has for capital, manpower, technical management, insurance and administration (Nilson 2010)

8.2.9 Quality of the vessel

The flag state of a vessel regulates which laws that govern both the commercial and civil activities on-board. Since each nationality has its own laws, the flag of registration matters. Ship owners can register their ship in open registers, called flags of convenience, to benefit from commercially favourable terms (Stopford 2009). The quality of the world fleet varies, generally the highest standard vessels are registered under the flags of traditional maritime nations (Nilson 2010).

Standard classification approvals are gained from a classification society, which serves as the industry's regulating bodies. The approved certificates serve as proof that the vessel's specifications are correct. Without approval from a classification society it is impossible to get the vessel insured, and the vessel would have little commercial value (Stopford 2009). There are about 50 classification societies in the world with a variety of standard. Since the classification assures a certain quality, the different class has influence on the freight rate (Nilson 2010).

Contaminated from either seawater or residues from previous cargo or lost can damage dry bulk cargo during voyage by for example technical malfunction (Stopford 2009).

8.2 Port Infrastructure

Ports play an important role in the transportation network as the interface between land and sea. Finding the most suitable port to be used in the transportation network is a trade-off between variables that are important for the parties involved. As with any business decision the different key variables must be carefully weighed before a decision is made. The port of choice ought to be in line with the overall logistic strategy of the company, considering cost, time spent in port and other value added benefits gained from using that specific port (Branch 2007).

For bulk commodities it is important with a short distance between the production site and the port, in order to decrease the Inland logistic cost. Hinterland connections to the port are another variable that decide the geographical location of the port. If the port is located close a trade route more vessels will be open for hire in that area, and since no detour is required for the ship owner the voyage time and back haul cost will be reduced. Physical restrictions of the port such as depth, quay length, storage capacity and facilities ashore determine the range of ports a vessel may call (Branch 2007). The speed of the loading activity influences time spent at the port. The capacity of bulk loading equipment is measured in ton per hour. Port fees and operator cost are also major factors (Talley 2009). In order to create a profitable and long-term relationship, the decision of what port to choose should not only be based on the most cost-efficient option, since it is equally important that the companies share the same objectives, levels of innovation and professionalism (Branch 2007).

8.2.1 British Columbia

There are over 20 ports in British Columbia used for trade of different commodities. The port facilities range between smaller ports that only handle forest products to larger ports with the most modern handling gear for bulk commodities with Capesize capacity. The distance from British Columbia to ARA is approximately 9380 nautical miles, if the route passes the Panama Canal (BIMCO 2011). The Panama Canal tolls 2011 for a round trip (excluding extra charges for brokers and so on) is:

Handy size	$ 111 860
Panamax	$ 207 172
Supramax	$ 142 772 (Panamá 2011)

The largest acceptable ship to transit the Panama Canal is called Panamax. The size is restricted to a length of 275 meter and a width of 32 meter. The average deadweight of a vessel of that size is between 65,000 - 80,000 ton, but the cargo intake is restricted to approximately 52,500 ton due to the draft capacity of the canal (Lloyd’s Register 2007).

8.2.3 Eastern Canada

Around the seaside of Eastern Canada the ports are restricted by the tides, which are among the highest in the world. The approximated distance from Eastern Canada to ARA is about 3000 nautical miles. There are more than 40 ports in the region, ranging from ports with Capesize capacity such as; Seven Islands, Port Cartier and Quebec City to minor ports that only can facilitate Handysize vessels (BIMCO 2011).

8.2.4 Liberia

Vattenfall currently uses the port of Buchanan in Liberia for loading wood chips (Sandberg, J). The distance from the port to ARA is about 3313 nautical miles. The port’s main restriction is the relatively shallow fairway with a depth of 10.5 meter. The commercial quay is 300 meter long. The combined properties mean that Supramax vessels of a size of approximately 50 000 dwt can enter. The loading capacity is 8000-10000 ton of wood chips per a day (BIMCO 2011). Vattenfall currently has a Contract of Afreightment for exporting woodchips from Liberia to Europe. The contract is at a relatively cheap freight cost with a fixed fuel cost clause (Christensen C, 2011).

9. Supply Chain Analysis

Although coal and BP will be used for the same purpose, they do not share the same market mechanisms and are sourced from different origins. This chapter will answer the question whether or not these two materials require two individual transportation corridors or not. Moreover, the supply chain of coal will be analysed to identify the point of interaction.

9.1 Aligning the Supply Chain Strategy

Implementing BP to the production of heat and power is a decision taken by the company owners, as a strategy to reach their business goals of lower CO^2 emissions and become carbon neutral by 2050. The energy market strives to produce power and heat at the lowest possible cost. Implementing BP is a question of spreading the risk and to have a diversified energy mix in order to stay competitive in the future.

According to Harrison (2005), the effectiveness of the supply chain strategies relies in the alignment towards the corporative and business units goals. This often rivals with other priorities through different stages of the organization. The product costs of BP is currently higher in comparison to coal, hence the cost to gain the same energy output increases when using BP, meaning that costs will increase in a short term perspective. In a long-term perspective costs are reduced as the product development proceeds and economy of scale is reached in the transportation leg and in the production facilities, together with the cost reduction for reducing CO^2 emissions. Hence, implementation of BP will have a negative impact for a number of departments as their priorities are in conflict with the long-term company goal. For example, the logistics cost will increase.

When deciding on logistical strategies for BP, one has to bear in mind that the supply chain of coal will be impacted, as less coal will be needed in the system. The system will be more constraint as both physical and organizational resources will be shared which will reduce the overall capacity of the two supply chains. It will be a challenge of aligning the high inventory levels holds in the coal supply chain with the attempt of lowers the inventory levels in the BP supply chain.

9.2 Strategic Solution of the Coal Supply Chain

Vattenfall assures replenishment of coal to each CHP by continuous trading on the global market. As coal is purchased from different regions depending on the current price and quality there is no set re-order point. Coal is bought based on a predicted demand, nine to twelve months before it is shipped to Europe. On the other hand the demand of coal is subject to rapid changes as it depends on the daily demand of heat and power. Hence, the rapid changes on the demand side are in contrast to the inflexible supply side.

The business idea is to capture the spread between the cost of coal and the return profit from the generated heat and power production. Coal trade is governed by an index. The idea is to purchase coal to a price as close as possible to the index, not to lose money in relation to the market.

The economics of coal trading are related to timing. The knowledge of; when to buy coal to cover the base demand; when to buy more than the base demand to keep at a storage and; when to use inventories in waiting for better market opportunities - defines this speculative market where the monetary value of the commodity is fluid.

The origin of coal has little influence on the purchasing decision, what matters is the current price of the required quality. This makes it difficult to arrange long term shipping contracts, as the transportation and the vessel characteristics' needed would differ if the coal were purchased in Russia or Columbia. So the maritime freight is arranged and bought on the spot market approximately 30 days before it is shipped. This may be ideal when the freight rates are low, and less beneficial when the freight rates are high, thus this is a risk exposure. The shippers are given a 10 days window for delivery. Such a large window also increases the need of high inventory levels in the system.

Coal is purchased based on the forecasted demand for one specific CHP, meaning that coal is not sourced on an aggregated demand for all CHPs in Europe and coal is occasionally re-allocated during the sea voyage. This supply chain approach is called a pull-approach, as the coal is pulled in to the market to serve one specific demand (figure 12). These systems increase the overall inventories, as it is hard to forecast the exact demand required, meaning that it is necessary to have oversupply. The high inventories in the system are justified by the risks of going offline with a CHP. The costs of shutting down a CHP are so great that it defends holding large inventories in Europe.

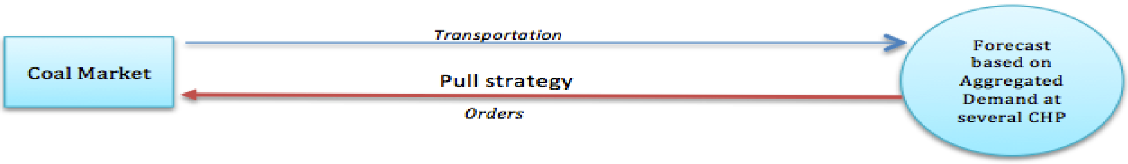


Figure 12 Pull approach in the coal supply chain

Inland logistics is bought -by a third party- around six months before the coal arrives at the port of unloading. The Inland provider is then given a 30-40 days window to deliver the coal at the CHP. This may reduce some cost for this transportation, but it means the transportation cycle time increases and that more coal is kept as inventory than if the delivery were scheduled to fit the demand of the CHP.

The supply chain relies in achieving high flexibility, which is done by increasing inventory levels and by relying on flexibility in both the sea transportation as well as in the inland-transportation system, which is adding costs. However these costs are justified by; the opportunity of trading coal when it is cheap, the risk of becoming out of stock and that the logistical costs only represents a small share of the landed costs for coal. However, we suggest that the coal supply chain management should improve the transportation cycle time, to reduce the levels of inventory in the system. To achieve this they must tighten the inventory management and inventory precision and apply a logistic philosophy.

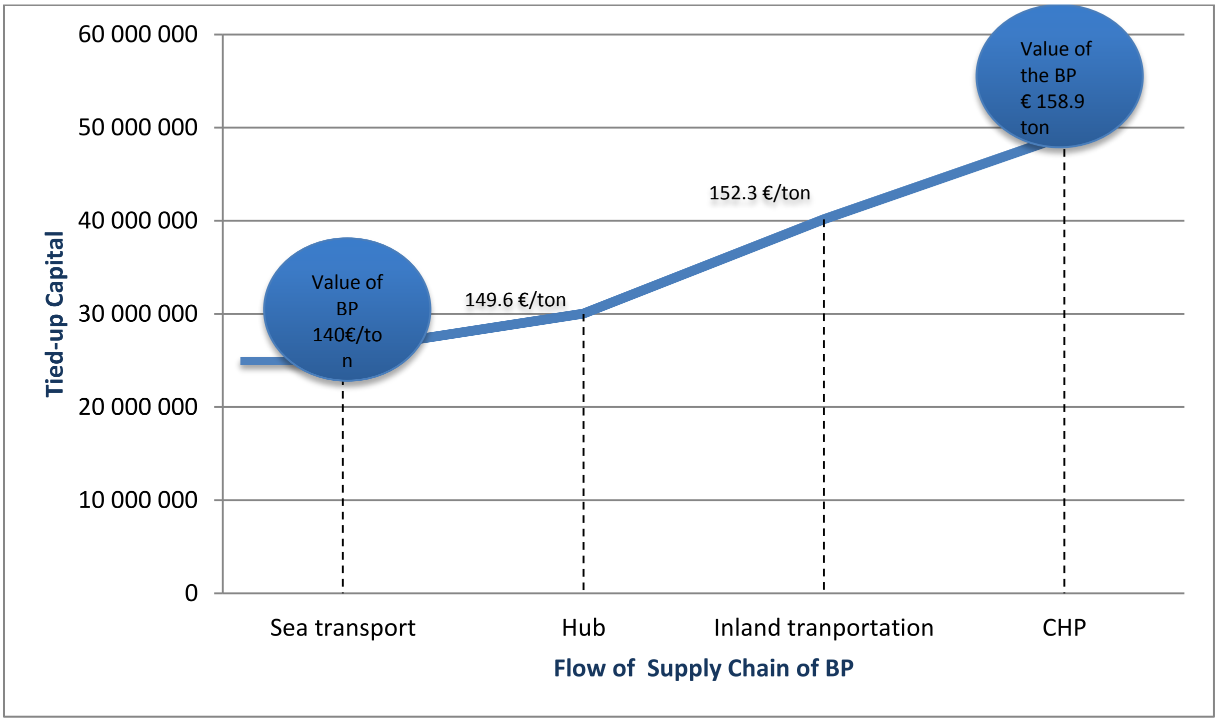
9.3 Strategic Solutions to Introduce Black Pellets

Vattenfall will control the price of BP by investing in both the feedstock and the production. By controlling the production they have the opportunity to reduce inventory levels, as well as planning the transportation network to achieve low costs. It is critical that the logistical costs will be kept as low as possible, especially in the beginning of the implementation of BP when the amount compared to the amount of coal is little and the possibilities to achieve economies of scale are modest. Demand of BP will not have variability between the four quarters of the year in this report, however in reality the demand will depend on the energy market and the demand for heat and power hence vary day and day.

9.3.1 Tied up Capital for Black Pellets

When actors like Vattenfall invest in the whole supply chain they must ascertain that the value of the product in the future at the end customer, in their case the CHP, must be less than if bought and delivered by a competitor. The logistics costs represent a high share of the total landed cost for BP, since the costs of transporting the material is added to the value of the material.

According to Jonson (2008) it is important to identify were the capital is tied up in the supply chain in order to know where to hold stocks. The further downstream supply chain the more capital is tied up. In following graph 4 we will show how capital is tied up in the BP as it is transported and stored in the supply chain.



Graph 4 Tied-up Capital 2013

The graph illustrates how the value of BP increases as it is transported from the production plant in Eastern Canada to the power plants in Europe. The cost of the product will vary throughout the SC as transportation costs, handling costs and storage costs is added to the initial cost at the port of loading. The tied-up capital in this graphic is based in the average stock multiplied by the value of the product at each stage (table 6). This example represents the flow of BP during 2013 by using 1 Handysize and 7 Panamax to the power plants of Reuter West, Hemweg and Buggenum.

Tied-up Capital 2013 Eastern Canada to of Reuter West, Hemweg and Buggenum

Nod in the SC	Value of BP (€/ton)	Average stock (ton)	Tied-up Capital (€)
Sea transport	140	186 057	26 048 029
European Hub	149.6	26 600	3 970 202
Inland Transportation	152.3	64 443	10 134 249
At CHP	158.9	56 484	8 977 381

Table 6 Summary of Tied-up Capital Calculations

9.3.2 Push pull strategy

Due to the importance of reducing logistics cost, the expensive flexibility gained from large inventories is an issue to be considered. As for coal, the service level at the CHP must be reliable due to the high cost of going offline. The trade-off between sufficient inventories and the cost of going offline is critical to decide upon. The fact that power or heat cannot be stored, imposes a risk of obsolesce. For these reasons, a pure push strategy becomes expensive.

A pull strategy is not recommended as it increases the risk for the bullwhip effect that can cause incorrect forecasts and over-supply of inventory in the system (figure 14). Black pellets will be sourced globally, so the lead-time from production to CHP will be long, which is another conflict of a pull approach.

A push-pull strategy is therefore proposed in order to achieve low inventory levels throughout the system as well as low transportation costs. With the long lead-times that appear with global sourcing, it is important to lower the transportation cost per unit, which is done by using the largest vessel possible. The capacity of the inland-transportation is lower than the capacity of the sea transportation. Consequently, it will be necessary to have a storage site at the port in Europe. The boundary between push and pull will be located at this point. By making the separation between the two approaches there, it is possible to optimize the two different capacities in the system, whilst lowering the overall logistic costs (figure 13).

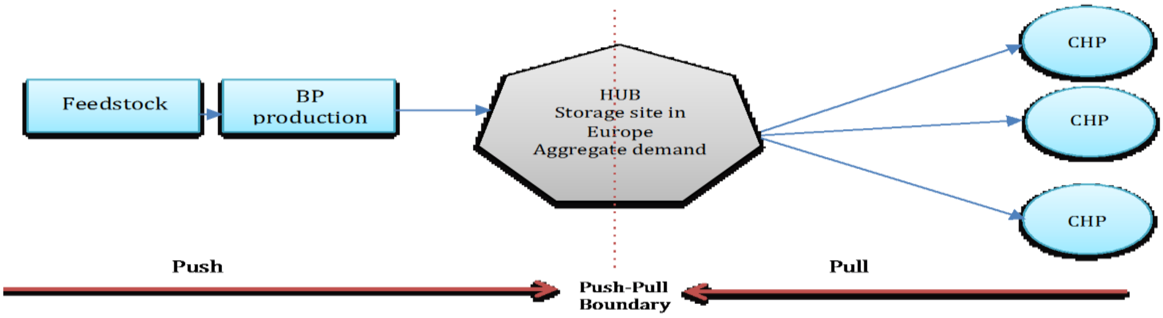


Figure 12 Push-Pull approach for Black pellets

Aggregated demand forecasts are more accurate than single demand forecasts. Based on long term forecasts from all of the CHPs, BP will be pushed in to the hubs in Europe. Aggregated demand has a higher possibility to gain from economies of scale, compared to the demand from a single CHP. Long lead-time will increase inventory in transit and thereby the working capital, it is therefore important to lower the amount of inventory in transit as much as possible, this is done by putting the aggregated demand on the same sea transport. Thus, there is a trade-off between lowering the transportation cost per unit and the risk of putting too much BP on one vessel as this increase the tide-up capital.

The pull approach will be used from the port in Europe. Between the hub at the port and the CHP the lead-times are significantly reduced. It will be possible to re-allocate the material, with the purpose of coping with the variations in demand. With short lead-times the system will have a higher ability to respond to changes in demand, which will decrease the overall inventories in the system, since no CHP will have more inventories than necessary.

9.4 Safety Stock

Safety stock is extra inventory held to mitigate the variability in the supply chain. Keeping inventory is a trade-off between the capital cost and the risk of becoming short of supply. The price of going offline with a CHP is enormous. It is therefore of great importance to set a well-balanced safety stock level. One of the major arguments for the push-pull approach is to keep low inventories, in particular low safety stock. Since aggregated demand will be held at a hub, the lead-time used to calculate safety stock is only the lead-time for the inland-transportation, which significantly reduces the safety stock.

According to Jonsson (2008), the manual estimated method, as described in 6.2.1.1. is the most accurate method for setting the safety stock for BP. This method weighs in experience, tied-up capital, storage cost and lead-time as main factors.

Focusing on the issue of tying up capital, it would be more beneficial to keep the majority of the safety stock at the hub rather than at each CHP, especially considering the short lead-time from the hub to each CHP and the capacity of the inland transportation system linking them.

Another reason that justifies a reduced safety stock of BP is the possibility to switch to coal. Due to the speculative trading patterns of the coal market, stock is generally never a problem. However, when coal is burned instead of BP, it will become necessary to burn more BP during the coming weeks, to elude costs for CO^2 emissions, meaning that the problem is only postponed. Thus, the overall levels of coal will be reduced when implementing BP, meaning that extra level of inventory could be minimized in the future.

9.4.1 Safety stock to the Netherlands

For Buggenum in Netherlands, the lead-time is 2 days from OBA. We propose that they keep a safety stock of 4 days, in order to have time to replace the order in case of sudden variations in the supply chain.

For Hemweg, the lead-time from the OBA terminal is almost negligible as the commodity is transported by conveyor belt. Although it is important to keep a safety stock for that very reason, if something would happen to the conveyor belt it is crucial that there is safety stock at the CHP. We suggest a 3 days demand of safety stock.

9.4.2 Safety stock to the Hamburg area

The lead-time from Tiefstack and from Moorburg to Hansa-Port is less than 1 day. If we use the same argumentation as in the Buggenum area, safety stock should be set to 2 days. However, a 2 days safety stock is by experience considered low, more so for a low-value material such as BP. The risk of variations in the supply chain and difficulties in predicting lead-time due to lack of in-house barge capacity justifies an increased safety stock to 3 days.

Moorburg has port availability and if a pure pull approach is applied, with a direct delivery from one of the global production plants to Moorburg, the safety stock has to increase. This is to cover the long lead-time.

9.4.3 Safety Stock to the Berlin Area

The lead-time from Hansa-Port to the Berlin area is approximately 3 days. Following the above argumentation, safety stock would be set to 6 days. However, considering that these CHPs are located close to each other, a different analysis applies. Reuter and Reuter West share the same storage site, and Moabit is located in the same area. If Moabit would run out of stock it is a possibility to trans-ship material from Reuter West/Reuter by train. If large variations in the supply chain occur for one of the CHPs, it will still be enough inventories at the storage site to cover the shortage of stock. We argue that a black pellets safety stock that covers 4 days of demand is sufficient to get a new delivery of black pellets in time.

9.5 New Bulk Materials in the Existing Supply Chain

Introducing BP to the coal supply chain will have an effect on both the physical as well as the organizational facilities in existing system. From the port of origin, the two materials will be shipped on separate vessels. Since it is an overcapacity of bulk carriers at the market, freight capacity will not be a limiting factor. The first interaction between the two materials will be at the storage site at the ports in Europe. Black pellets and coal will be stored in separate piles and never be physically mixed at this stage. Since the storage at the ports is owned by 3PL, Vattenfall will not need to organize the storage capacity.

Both BP and coal will be transported from the port by barges; however the two materials have to be separated and cannot be put on the same barges. Black pellets will add volume requirement to the system, so the capacity of the inland-transportation network may be conflicted. Storage sites, conveyor belts and handling equipment at each CHP also have limited capacity. For these reasons it might also be necessary to co-organize these points of interaction in the supply chain, see figure 14.

We propose that the supply chain approach for coal and BP should be kept apart. They should be treated as two individual supply chains since they have different market mechanisms. Although, it will be crucial to make an additional and common strategy for the two supply chains, as they will have the same propose of serving the CHPs with fuel to generate heat and power and since the demand for each product will be based on the same forecast.

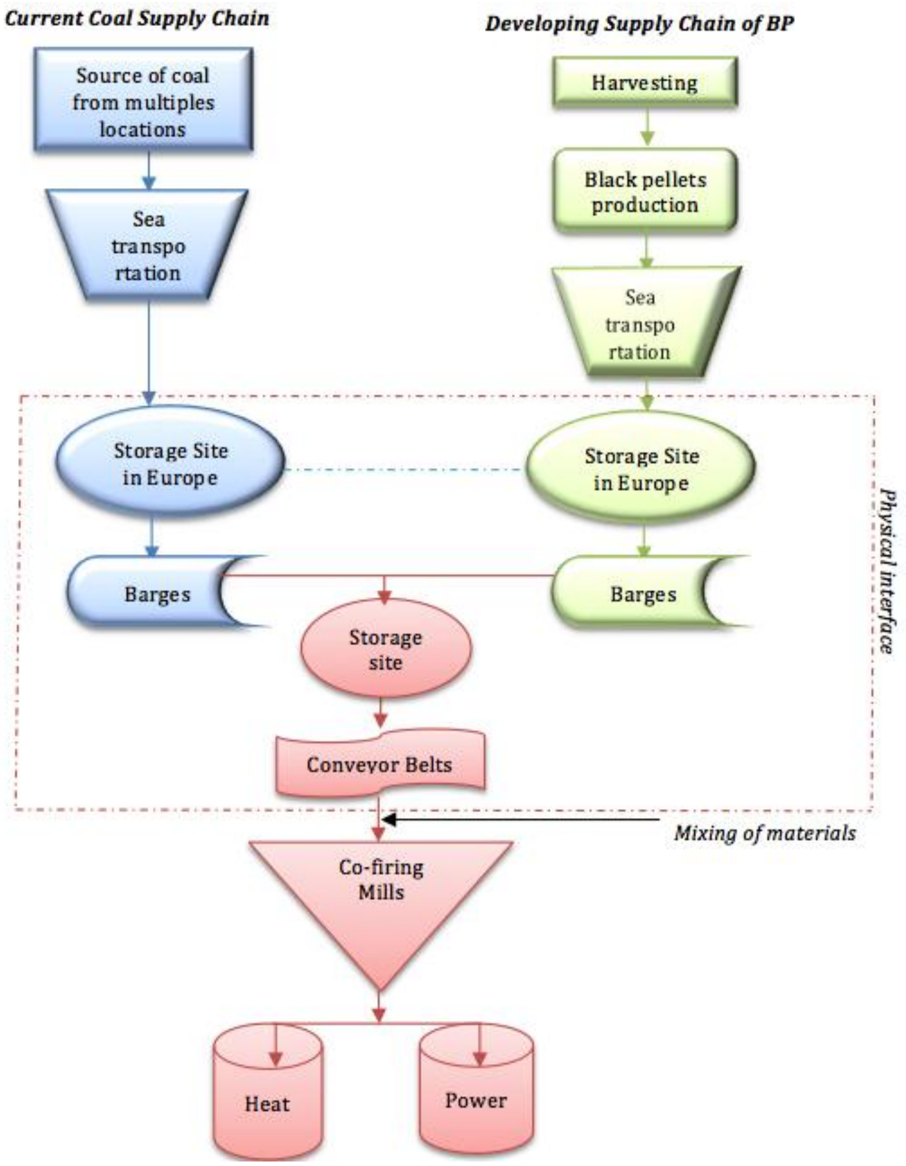


Figure 14 Interaction between the two supply chains, BP and Coal

If Vattenfall decides to produce BP with propose to put them on the market to other energy companies to buy, the supply chain will be influenced. However we claim that BP produces to sell this should be treated as a separated SC, not to be mixed with the in-house use of BP at Vattenfalls CHPs.

10. Design of the Transport Corridor

In this chapter the transportation corridor is designed. There are different approaches when designing a bulk transportation supply chain, depending on what variables are considered most important. In order to investigate the different options, we performed a trial and error calibration, based on the transportation costs and inventory costs, to find the most suitable vessel size to supply the CHPs in Europe.

10.1 Global Transportation Corridor

Designing a transportation corridor involves several variables such as annual demand, variations in demand, service levels, lead-times, transportation costs, overall cost and so forth. The analysis of these variables supports strategic decisions regarding transportation modes selection, inventory levels and order cycle.

10.1.1 Shipping leg

The characteristics of BP allow the company to use know-how of the shipping market for coal. Moreover, the same vessel type - dry bulk carriers, port facilities and storage at the ports can be used.

The location of a BP production site determines the port of loading. As mentioned in the theory chapter 8.2, the port of loading will influence the vessel size, which is also the order quantity that determines the inventory levels. The exact locations of the production in British Columbia and Eastern Canada are not decided at this point. Hence, there is no set restriction for the vessel size due the port of origin. The calculations will show the relationship and trade-offs between vessel size and inventory levels.

The most important characteristic of the port that will be used on the eastern coast in Canada is the restrictions on the vessel size that may enter. In order to gain economic of scale, large vessels such as Capesize, are the most suitable to use.

In these calculations the authors has chosen to use the time charter prices from the FFA's when calculating the shipping freight. FFA is the only figure on the market that deals with future freight prices. One could use an average historic price but this differs tremendously from the FFA, as the peaks from 2008 are included. We consider that the average does not reflect the current and future situation of over-supply of bulk carriers on the market. After having consulted various entities with shipping market knowledge, they agree with our assessment.

10.1.2 Shipping Contracts for Vattenfall

The four different contracts mentioned in the shipping chapter above come with different risks as well as different needs for knowledge of shipping and the shipping markets. By distributing the share between voyage and time charter contracts the charterer will hedge his risk. Voyage charters require minimal knowledge of shipping, as it is a rather straightforward purchase of a transportation service. It offers full flexibility, but cost is difficult to predict as deals are negotiated on a spot market.

Contract of Afreightment is a suitable contract for shippers like Vattenfall who have a secured amount of cargo to transport from one point to another. The CoA is a complex and detailed contract that can take long time to agree upon. Therefore it is important to have good shipping knowledge to gain a favourable contract. As both the operational and shipping market risk is put on the ship owner, the freight is prone to increase but on the other hand the risk assortment is positive.

We would not recommend Vattenfall to buy their own vessel when they have enough BP to justify the investment. We believe that it is a large risk to invest in a vessel, as managing a vessel is outside Vattenfall’s core business. It would also mean that they have to recruit experienced personnel to operate the vessel and be sure that the investment will pay off in a long term perspective.

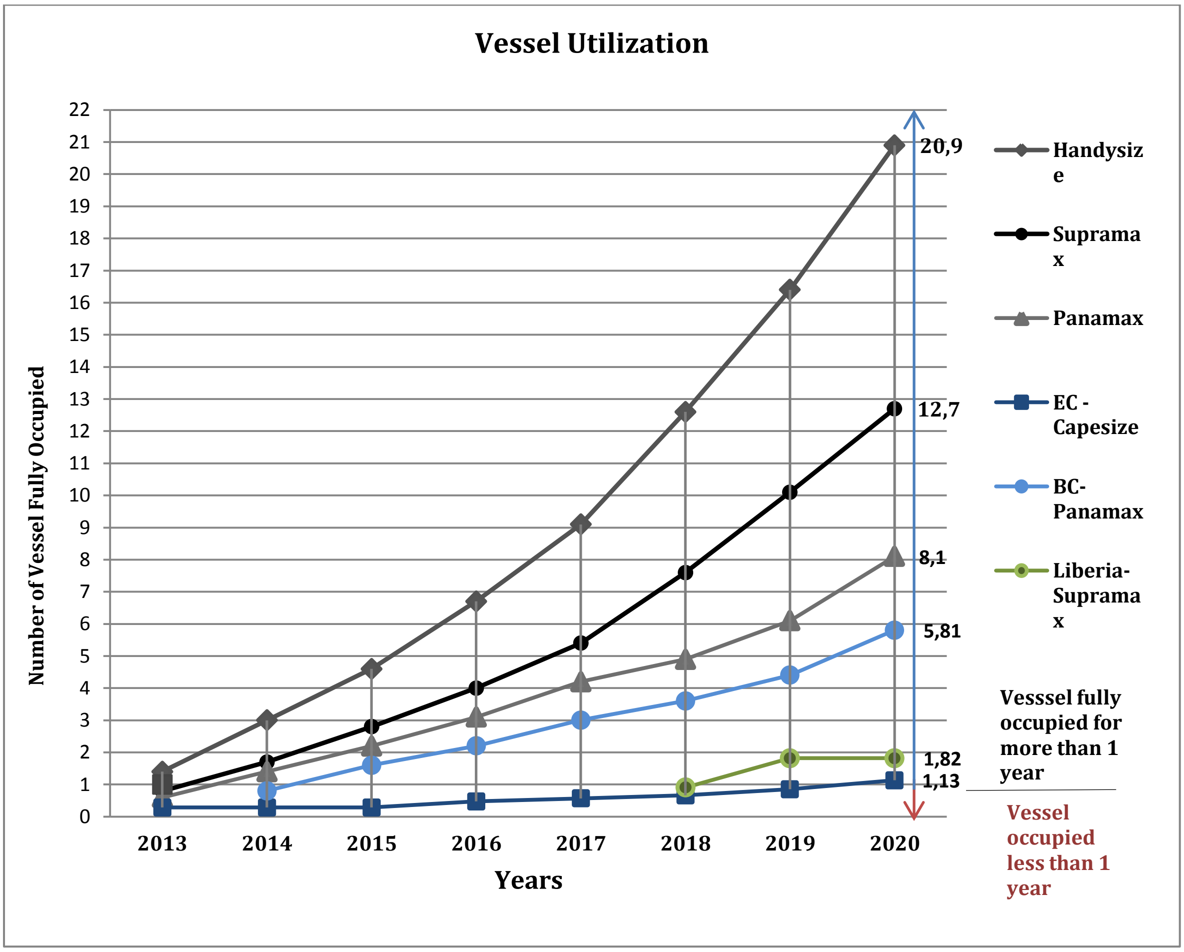
If Vattenfall decides to buy a vessel they have the option of buying a vessel from the second hand market or order a new building vessel. The first option is the one we recommend Vattenfall to do since there is an overcapacity of bulk vessels on the market.

There is a global imbalance in the flow of goods for bulk commodities. This influences the freight rate as the cost for one voyage includes the back haul trip. This will have a high impact on the transportation cost for BP, especially on the long distance trip to British Columbia where there are almost no return flows from Europe. If Vattenfall decides to buy a vessel they will most likely consider finding cargo to fill the back haul to minimize the sea transportation cost. It must be highlighted that this will come with a risk of not having the vessel ready when it is needed to manage the freight transportation of BP. If one would like to find back haul cargo it also requires more shipping knowledge as well as shipping market knowledge. The additional time needed for the detour must also be calculated.

10.1.3 Vessel Utilization

In order to negotiate shipping contracts, especially time charters, Vattenfall must know at what point they have enough supply of BP throughout the year to continuously utilize a vessel. This is depending on yearly aggregated demand, vessel size and lead-time of the round voyage. The lead-time is set by the distance between the port of origin and the port of destination; hence it cannot be influences except by changing one of the ports. Since the assumption is that the vessel will not be used for the back haul voyage, the lead-time is calculated for the round trip, meaning that this is the frequency of one vessel (graph 5).

The graph illustrates the number of fully employed Handysize, Supramax and Panamax vessels needed to supply the aggregated demand in Europe from the three regions of origin for every year. For instance, in 2020, 20.9 Handysize vessels can be fully occupied. The graph also shows the number of vessels of the largest possible size to be used from the three production sites. Nearly six Panamax can be fully utilized from BC. One Capesize can be fully utilized from EC and less than two Supramax from Liberia during 2020.



Graph 5 Vessel utilization

10.1.4 European Hubs

Ports in Europe are generally well developed, and for this transportation corridor we have chosen to use IJmuiden in Amsterdam and Hansa-Port in Hamburg as ports of discharge. The push-pull boundary is located at this point.

Hansa-Port is chosen as the hub for the CHPs in Germany during, spring, summer and fall. The storage capacity is 400 000 ton, the port is owned by a third party. Currently the port has a limited storage time of 3-4 days. This constrains the transportation corridor, but the authors assume that this can be solved through negotiations with the third party. Hence, this should not cause a problem in the future. There is an additional storage site in the same region, at the CHP Wedel, which is owned by Vattenfall. However it is not equipped with the necessary handling equipment to serve as a hub at this stage. Investments are required for this plant to be used as a storage site for BP in the future. Until then, it is suggested that Hansa-Port is used as a hub for the CHPs in Germany.

During winter when the waterways to Berlin are frozen, a similar alternative to supply the CHPs in the Berlin area will be applied. The aggregated demand for BP will be shipped to the OBA terminal to be transported by barge to Duisburg in Germany, to be reloaded onto a train to and unloaded at the CHPs. Due to the delimitations this alternative will not be considered in the overall cost calculations.

At the port of IJmuiden the cargo is discharged and transported by barge to the nearby OBA-terminal, where it is stored. Port restrictions allow a 150 000 dwt vessel. The storage capacity at the OBA terminal is 2 million ton, of which 300-400 000 ton for Vattenfall's account. As it is a third party we assume that additional storage can be bought if needed. A first-in-first-out approach for BP should be applied at every storage site.

The corridor will mainly be based on the push-pull approach, but since the demand varies, the accessibility to seaports as well as the distance between them we suggest a pure pull approach for some routes.

10.1.5 Inland Transportation

Transportation modes used for the inland transportation will be the same as for coal. It is therefore possible to use the same third party transportation providers. This strategic partnership may bring advantages such as better freight rates.

The CHPs in this thesis are without exceptions located either at seaports or rivers. The most cost efficient inland transportation mode for bulk commodities is barges. Conveyor belt are cost effective and fast, but is only possible to use for shorter distances.

The barge capacity is equal the order size for the inland transportation, where capacity constrains the amount of BP that can be delivered per order. We have chosen to calculate on the maximum barge size allowed on each route. Cost for inland transportation is based on the aggregated demand for each CHP. Since we use the same inland transportation network as for coal, the total cost will only be affected by the increased demand at the CHPs.

10.2 Total Costs

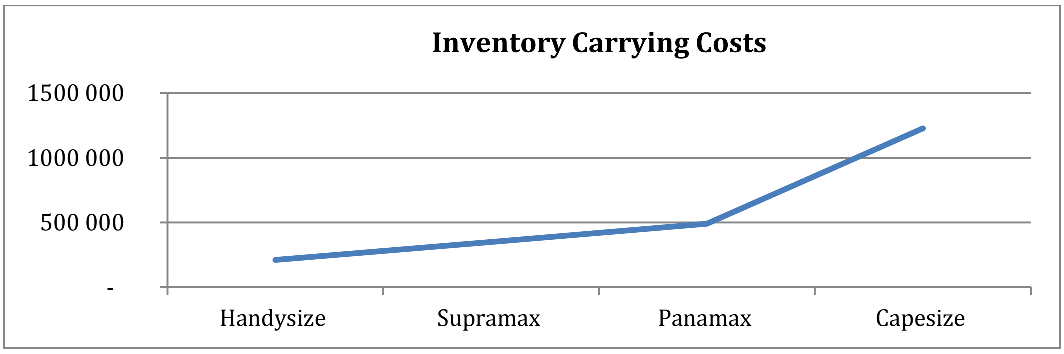
To calculate the total cost an adjusted EOQ-formula is used. The reason to use this relatively simple formula is that it contains few variables. When adding more variables biases would increase, and since the production of BP does not exist in commercial scale yet many variables are unknown. This is a tool used to illustrate how the trade-offs can be weighed when deciding on a transportation corridor. Moreover, the choice of formula is suitable for bulk commodities when there is small variation in demand. This report strives to provide the decision makers at Vattenfall a model on how the variables in the SC influence each other, rather than to provide a fixed solution.

Total annual costs (TAC) are the summation of the inventory carrying costs (graph 2), order costs (graph 3), transportation costs (graph 4) and in-transit inventory carrying cost. These calculations are based on the adjusted EOQ-formula showing the trade-off between holding BP in inventory, cost of placing an order and transportation costs (chapter 6.7.1).

The order size Q is fixed to the applicable vessel size for the shipping leg, and in the case of inland transportation for the barge size. Accordingly, the amount shipped from the port of origin and the hub cannot exceed the vessel or barge size.

10.2.1 Inventory carrying cost

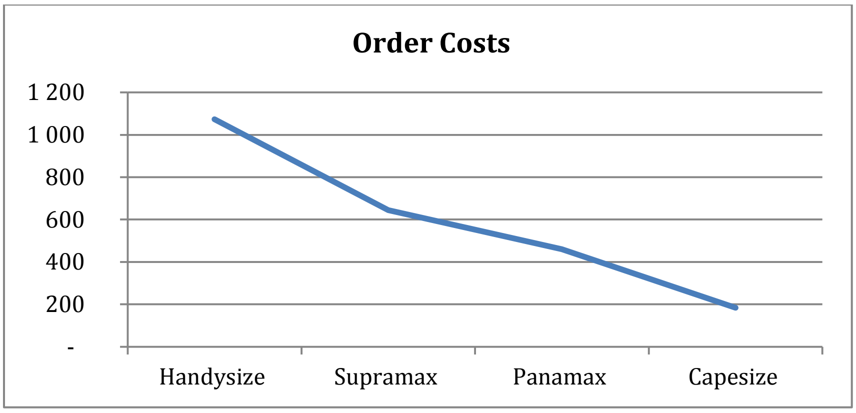
Inventory carrying costs increase in correlation to the order size, which is the size of the vessel (graph 6). For calculating inventory costs, costs of carrying inventory in warehouses are included as a percentage figure. Since Vattenfall was unable to set this figure the authors choose to use Vattenfall’s figure Return on equity – 10%. The reason is that the cost of tying capital as inventory can be can be compared to the possible return of investments. But, the figure for Return on Investments is confidential at Vattenfall so the Return on equity is used in its place.



Graph 6 Inventory carrying costs

10.2.2 Order cost

Contrary to inventory carrying cost, the order costs will decrease as the vessel size increase (graph 7). It is important to highlight the low order cost which is a common characteristic of bulk materials. Accordingly, the impact of order costs is relatively small in relation to the total inventory costs.



Graph 7 Order handling costs

10.2.3 Transportation cost

The number of vessels to be used is set by calibrating the supply from the three regions together with the aggregated demand and to the hubs in Europe. These calibrations take not only the lowest sea transportations cost possible in to account, but also the most suitable vessels considering sea transportation contracts and frequency of the deliveries (chapters 10.3-10.5).

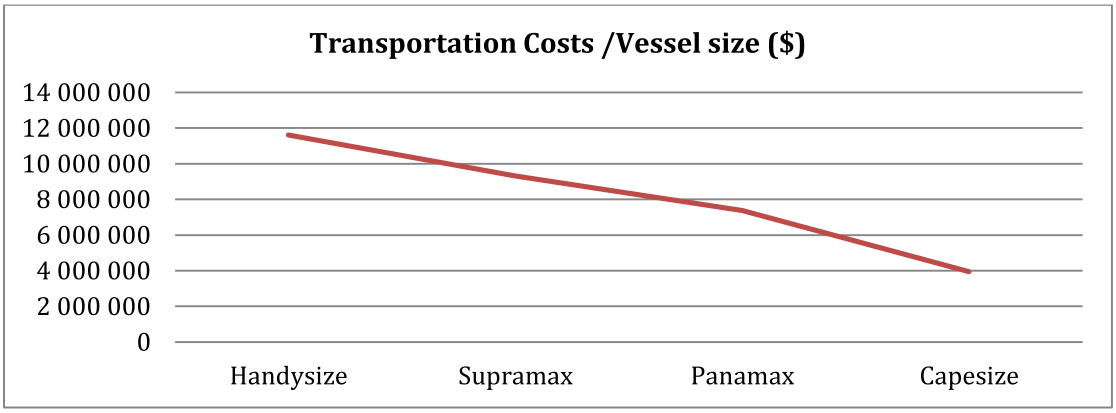
The transportation costs are divided in the sea transportation leg and the inland transportation leg. For the inland transportation the costs are fixed for every CHP. The shipping leg has to be designed in accordance with the strategic approaches for the black pellets SC.

Sea transportation costs are calculated based on number of vessels, the sea freight rate (found in 8.2.4.1), bunker cost (found in 8.2.5) and the lead-time - which is the average distance between the port of loading and port of destination, handling time for loading and discharging plus extra days at sea (appendix 2). For shipments from BC the Panama Canal tolls are added (found in 8.2.1). Graph 8 illustrates how transportation costs are decreased by the order quantity. The graph shows the annual demand of BP in 2013, from Eastern Canada to the Netherlands. The transportation cost increases as the order size decreases. Using a Handysize vessel will increase the total transportation cost compared to the same amount transported in Capesize vessel.

The lead-time is influenced by the vessel size, since handling time differs between vessel sizes. This is also due for bunker costs, but here costs do not increase in proportion with the vessel size. Hence it is not only the freight rate that sets the sea transportation costs (appendix 2).

For the inland transportation we calculate with the figures provided by Vattenfall, which include freight rate, bunker costs etc. (appendix 3).

Handling costs are charged by ton and will therefore not influence the total costs, and to avoid bias we have choose to exclude this from our calculations. The same goes for the costs of holding stock on storage.



Graph 8 Transportation Costs from EC to Hamburg

10.2.4 -transit cost

In-transit inventory cost shows the cost of having inventory under transit. The lead-time is calculated on an average lead-time set by the vessel sizes used for that year. Since Vattenfall owns the material while it is under transportation this cost must be considered.

Assumptions that are made for the cost calculations:

- Demand of BP is known for each CHP
- Demand is constant for each period
- Supply of BP is known for each production site
- The costs for placing an order is constant
- Demand at every CHP will be fulfilled
- There will be enough BP at the production side for all shipments
- The value of BP will be constant
- The use of BP will have an infinite planning horizon
- There are no restrictions of availability of capital when sourcing BP
- Speed for all vessels is 13 Knots
- Extraordinary conditions during winter time, such as ice etc. is not considered

10.3 Global Transportation Design

Global transportation corridor A. The distances between the three regions of supply are so vast that a combined sea transportation route is not proposed. Three individual legs make up the route design. From British Columbia the route passes the Panama Canal, adding costs and restricting the vessel size to a Panamax. This is the longest route and it takes around 30 days one way to get to ARA. From Eastern Canada to ARA the shipping time is approximately 9 days, and there is a limited number of ports in the area that accept the large Cape size vessels, but there should not be any issues finding a suitable port. From Liberia the port of unloading is Buchanan, with a lead-time to ARA of around 11 days. The port restriction allows Supramax vessels with a deadweight of 50 000 dwt (figure 15).

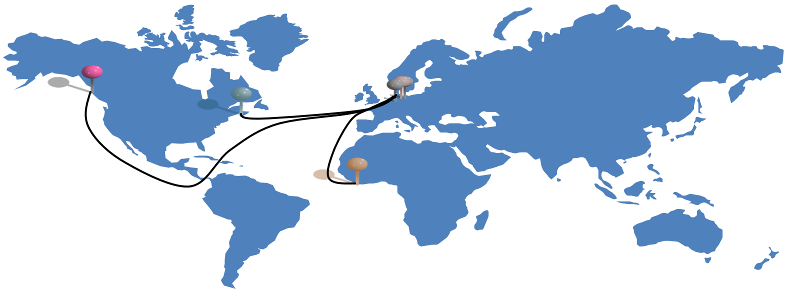


Figure 15 Global Transportation Corridor A

Global transportation corridor B. There are alternatives for the global shipping routes. From British Columbia BP can be put onto a train to be shipped across the continent to Eastern Canada. The supply from BC would be consolidated with the supply in EC. This alternative would allow larger vessels to be used from EC, compared to the vessel size limited by the Panama Canal. Further the Panama Canal fee would be avoided. The main drawback is the limited capacity of the train, especially when 2 Mton of BP will be transported in 2020. This corridor also requires additional handling of the commodity. Due to delimitations of this report this alternative is not analysed, however the authors believe that this alternative is worth further investigation (figure 15).

There is a second alternative for the shipping leg from Liberia that would be to use a storage site in northern Africa, for reloading to a larger vessel to benefit from economic of scale. This alternative requires additional handling, as well as extra storage management needed so we do not consider this alternative feasible (figure 16).

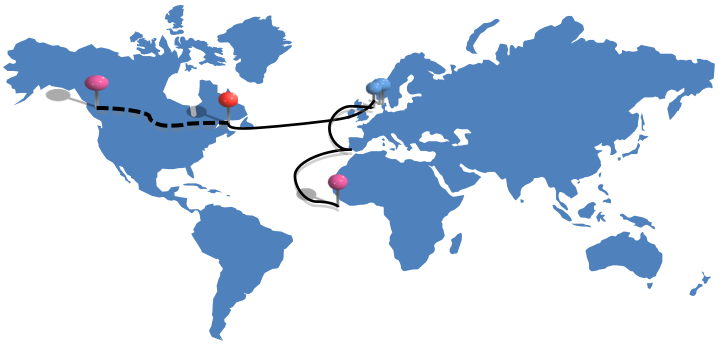


Figure 16 Global Transportation Corridors B

10.4 First Phase 2013 - 2015

During the first phase between the years 2013 - 2015 BP will be used in the two CHPs in Netherlands; Buggenum and Hemweg as well as in Reuter West in Germany. BP will be produced in Eastern Canada from 2012 and production in British Colombia will start in 2014. The demand during this phase is relatively small and since only one CHP in Germany will use BP during these years, the design of the transportation corridor will differ in comparison to the next two phases (see table 7).

Annual demand of BP during Phase 1

CHP	Demand of BP (ton) 2013	Demand of BP (ton) 2014	Demand of BP (ton) 2015
HKW Reuter West	192 910	257 214	385 820
Hemweg 08	232 921	310 561	465 842
Buggenum	89 204	148 674	148 674
Aggregated demand (ton)	**515 035**	**716 449**	**1 000 336**

Table 7 Demand of BP during the first phase

10.4.1. Design of the Transportation Corridor in Phase 1

Aggregated demand from all three CHPs is pushed in to the port of IJmuiden to be put at the OBA terminal for storage. From here barges transports BP to each CHP on a pull approach (figure 17). For the inland transportation to Reuter West, BP will be put on a feeder vessel and shipped to Hansa-port in Germany. Here the commodity will be discharged and loaded onto a smaller barge with a capacity of 1500 ton, the lead-time for this is 7 days. A conveyor belt will be used to supply the daily demand of BP to Hemweg. Barges will be used to supply Buggenum, with a capacity of 3200 ton, the lead-time from the terminal to the station is 2 days including unloading and loading. The main constraint at this CHP is that only one barge can be discharged per day, but this will not cause a bottleneck in this first phase.

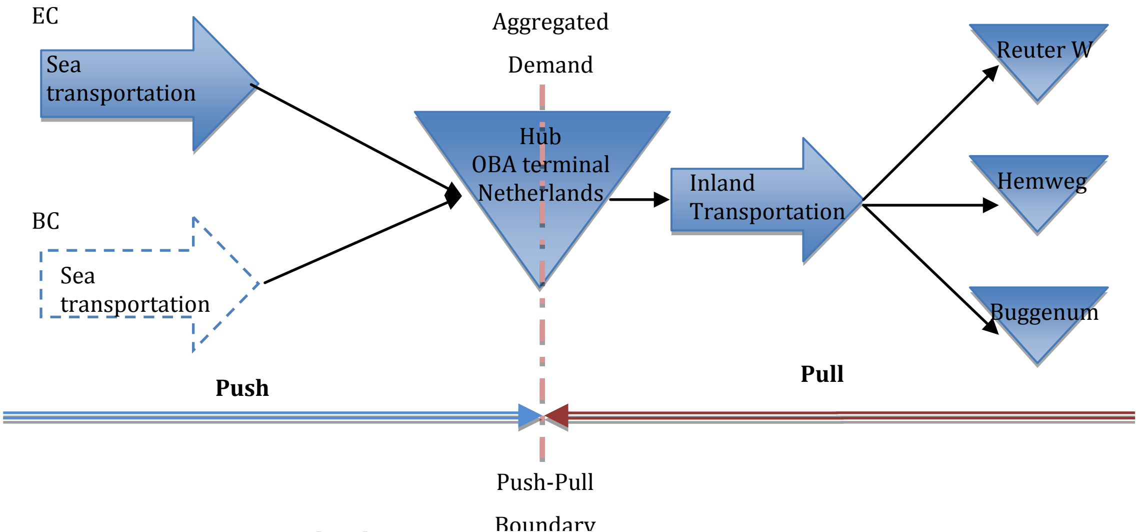


Figure 17 Transportation Corridor Phase 1

We suggest Vattenfall to use this design since it has the lowest total cost and since it benefits from the push-pull approach discussed in (chapter 9.3). The main disadvantage is the double handling cost needed to supply Reuter West.

10.4.1.1 Transportation corridor 2013

Cost calculations for the transportation corridor in 2013 shows that the lowest transportation costs for the shipping leg from Eastern Canada to the port in Netherlands is given if 3 Capesize vessels are used (appendix 1). This will lower the transportation cost per ton, but it will mean that the supply will come less frequent, only every fourth month. Moreover, this option will increase the inventory costs and the risk of having capital tied up in one large vessel. The solution is to use 7 Panamax and 1 Handysize to increase the frequency of the deliveries and reduce the risk of holding large inventories.

The lead-time between Eastern Canada and IJmuiden is about 30 days, including voyage time, loading and unloading as well as a couple of extra days at sea. To utilize one-vessel 100% 12 voyages is needed per year (chapter 10.1.3, table 8). Since this is not the case in 2013 we suggest Vattenfall to by the freight capacity on voyage contracts for this year.

10.4.1.2 Transportation corridor 2014

For the next year production from British Columbia is added to the system. Panamax is the largest vessel size to deliver BP from that region, when passing the Panama Canal. There are two options for the shipping leg, either to use 3 Capesize from EC and 4 Panamax from BC. The second option that is recommended is to use only Panamax vessels; 4 from BC to Hamburg and 7 from EC to ARA (appendix 1). Counting on the round-trip it means that 1 vessel can be utilized 100% on a T/C contract and the additional capacity has to be bought on the spot market. This may increase the cost per ton, but it also gives an opportunity to contract the shipping freight to a longer-contract, thus ensuring both freight capacity and freight rate over time (chapter 10.1.3, table 8).

10.4.1.3 Transportation corridor 2015

In 2015 the demand increases and additional supply is added from BC. The lowest overall costs are gained by using 8 Panamax voyages from BC and 3 Capesize voyages from EC (appendix 1).

The alternative is to use Panamax vessels from both EC and BC. 15 Panamax shipments are needed from these regions, which is enough to occupy two vessels 100 %. This option will increase the transportation cost per unit, but it also increases the frequency of the deliveries and lower the inventory levels. By using only one type of vessel, Vattenfall also has the opportunity to negotiate a long-term T/C contract, hence this is the option recommended for this year.

10.4.2 Alternative Design for Phase 1

The alternative would be to use two hubs, one at the OBA terminal in Netherlands and one at Hansa-Port in Germany (figure 18). The aggregated demand to Hemweg and Buggenum would be sent to OBA on a push approach followed by inland transportation in a pull approach, as in the above design. To supply Reuter West a pure pull system will be applied, with a direct shipment to Hansa-Port. Once the ship is unloaded in Hansa-port the BP will be transported by barge to Reuter West.

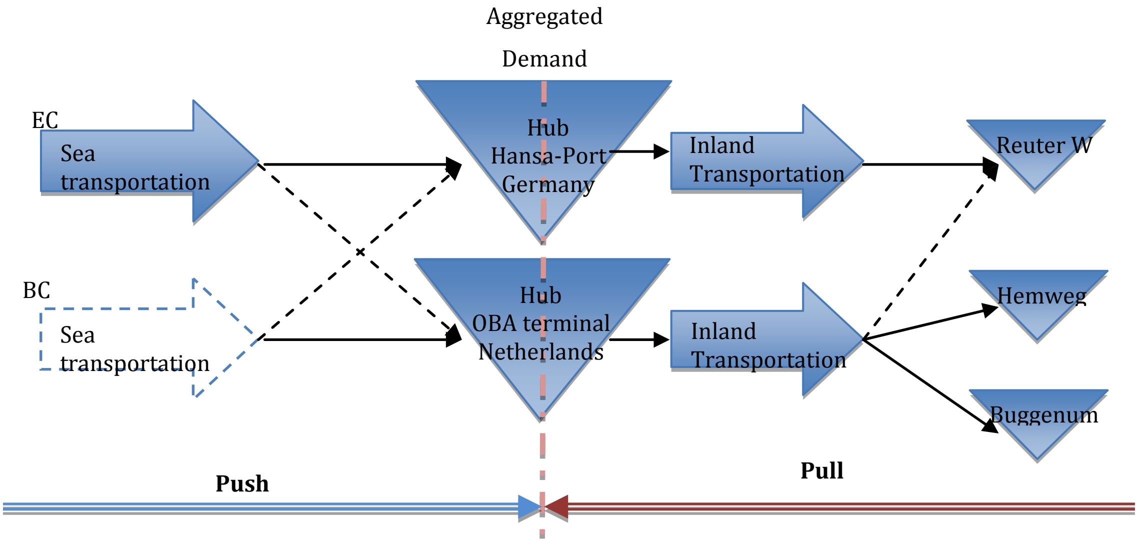


Figure 18 Transportation corridor (phase 1) 2013-2025, Alternative 2

This design would avoid extra handling costs, which according to Stopford is one of the main targets when designing a bulk transportation system. However, the trade-off is both extra inventories in the system, as well as a higher transportation cost per unit as smaller vessels has to be used, which causes a higher total cost compared to the chosen alternative. However, this design is an option for the future flows, when more CHPs are using BP in Germany and should therefore not be ignored.

10.5 Second Phase Year 2016

During 2016 Reuter and Tiefstack, will begin to use BP in their power and heat generation. Production will continue from Eastern Canada and British Columbia. The additional two CHP in Germany motivates a push-pull approach for aggregated demand in both The Netherlands and in Germany. Hence, there will be two hubs, one at Hansa-Port and one at the OBA-terminal, see figure 19.

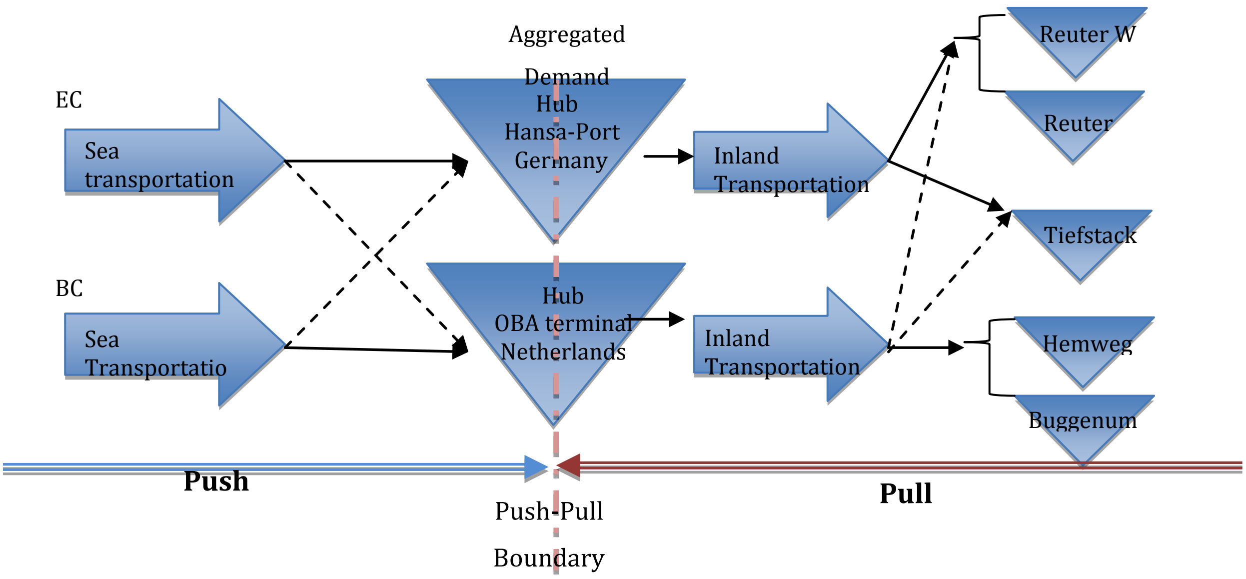


Figure 19 Transportation Corridor 2016

The size of the vessel represents different alternatives for the sea transportation leg, illustrated in table 10. Each alternative has pros and cons that should be highlighted before taking a decision of what contracts to settle. We suggest Vattenfall to choose option 5 since this represents the lowest transportation costs.

Transportation Alternatives for 2016

Options	**Voyages**	**Sea Transportation costs (ton/$)**	**Pro**	**Con**
Option 1	25 Handysize from BC 25 Handysize from EC	$ 62,8	Frequent deliveries Low inventory levels	Expensive More administration
Option 2	15 Supramax from BC 15 Supramax from EC	$ 49.0	Frequent deliveries Low inventory levels	Expensive More administration
Option 3	11 Panamax from BC 11 Panamax from EC	$ 38.3	2 T/C contracts Frequent deliveries Small inventories	Relative Expensive
Option 4	11 Panamax from BC 4 Panamax from EC 3 Capesize from EC	$ 35.7	2 T/C contracts 2 Different contracts	Large inventories High capital costs
Option 5	11 Panamax from BC 4 Capesize from EC	$ 33.2	Less costly 2 T/C contracts 2 Different contracts	Non-frequent deliveries Large inventories High capital costs

Table 8 Sea Transportation Alternatives for 2016

The aggregated demand for the hub in the Germany represents 4 Capesize voyages shipped from Eastern Canada. The total voyage time between EC and Europe, including laden voyage and ballast, is about 40 days, meaning that one vessel will not be occupied fully this year. This indicates that these voyage should either be bought on the spot market or that a CoA should be contracted for these four trips.

To supply the aggregated demand at the hub in the Netherlands, 11 Panamax vessels from British Columbia is needed. This indicates that 2 Panamax vessels would be fully occupied to supply this demand during this year, with an additional 2 voyages to be bought on the spot market to hedge the shipping risk. For this year we recommend Vattenfall to make a long-term contract for the British Columbian route (table 8).

For the inland transportation, the two hubs will provide each CHP with the demand they need, since the push-pull approach is applied we presume that there is enough inventory at the hubs to supply the CHPs. The number of barges needed to the Berlin area is 387 and the total cost for this is 6.65 million € (appendix 2).

The total sea transportation costs from British Columbia to ARA in a Panamax is $ 35.1/ton compared to 13.2 $/ton if a Panamax is used between Eastern Canada and ARA. This indicates that the future price of BP from BC must be reduced to gain profit from this area.

10.5 Third Phase 2017 - 2020

In the last phase between the years 2017 - 2020 the final two CHPs will start to use BP to generate heat and power, Moabit in the Berlin area and the newly built power plant Moorburg in Hamburg (appendix 2). Production of the material will continue to be located in Eastern Canada and British Columbia. Additionally, in 2018 the production of BP from Liberia is added.

Third phase - Black pellets production (ton)

Year	**2017**	**2018**	**2019**	**2020**
EC	1000000	1250000	1500000	2000000
BC	1000000	1250000	1500000	2000000
Liberia		500000	1000000	1000000
Sum	2000000	3000000	4000000	5000000

Table 9 Black pellets production third phase

During this phase both demand and supply are rapidly increased, see table 9. An additional 1 Mton is added to the system yearly. To supply the CHPs in the Netherlands during 2017, 6 Capesize voyages are needed from EC, with a frequency of one delivery every month. To supply the demand in Germany 15 Panamax voyages are needed, theoretically occupying 2 vessels for one year. The additional freight capacity has to be bought on the spot market (figure 20).

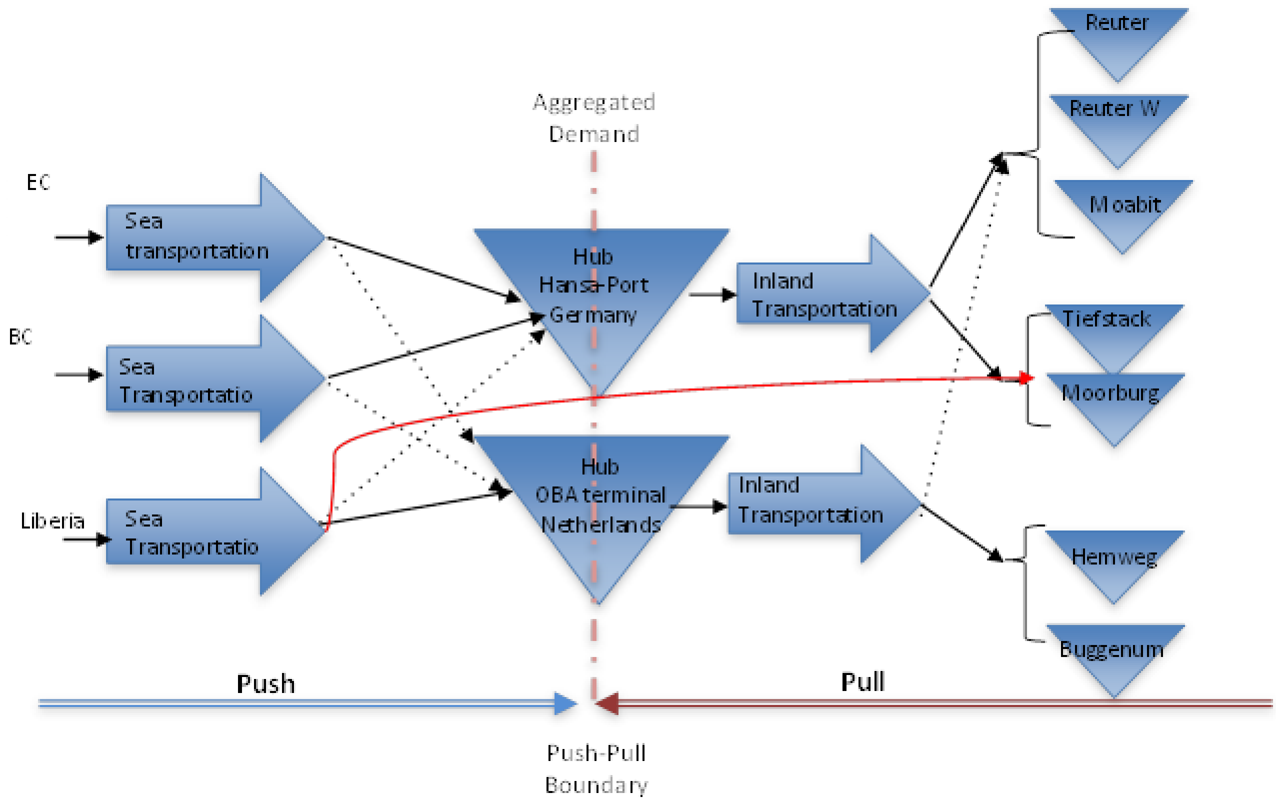


Figure 20 Transportation Corridor 3 Phase (2017-2020)

Liberia will begin by producing 500 000 ton of BP in 2018. The limit capacity at the port is 10.5 meters, indicating that a Supramax vessel is the largest vessel that can operate this route. This indicates that 10 Supramax voyages are required during the first year.

From 2018 demand and supply will be sufficient to use the largest possible vessel from each region to meet the required frequency of deliveries. It is therefore recommended to use Capesize from Eastern Canada, Panamax from British Columbia and Supramax from Liberia to decrease the transportation costs (appendix 1). They should have long-term contracts, presumably CoA to lower their overall costs.

In 2019 and 2020 the production is up to 1 Mton in Liberia, and 20 Supramax voyages can be filled. If it were possible to use a Capesize from Liberia to Europe the transportation cost would be reduced from $ 18.8/ton to $ 8.3/ton.

The new CHP Moorburg will consume large amounts of BP. The port restriction at the CHP allows Supramax vessels to enter. We recommend Vattenfall to ship directly to Moorburg. This solution avoids extra handling costs. To avoid constraints caused by the limited storage capacity it is needed to supply the CHP with frequent deliveries.

For the inland transportation in 2019 and 2020 the two hubs will provide each CHP with the demand they need (see total inventory cost at appendix 3). The study shows that it would be possible to ship coal and BP on the same type of barges, hence one barge can be used to supply the two materials in the system. The number of barges needed, to supply Buggenum with BP, 2019-1020 is 130 per year. The lead-time for a round trip is 3 days, meaning that 1 barge can be used to cater the basic demand. However, one tugboat is pushing two barges, making it necessary to acquire two barges and one tugboat. This indicates that Vattenfall will not have a sufficient flow of BP to justify an acquirement of barge to use in-house. But as coal will be co-used at the CHP, the amount of cargo will be enough to justify an acquirement of two barges and one tugboat.

For the Berlin area, with the most frequent need of barges to supply the required demand, there is a problem during winter when the waterways freeze and barges cannot be used. This makes the question of acquiring capacity more complicated and one has to be sure that the money saved with running ones barge will make up for the time when they are laid up.

11. Bottleneck Analysis

This bottleneck analysis is based on interviews and theoretical information, the intention is to point out where the major bottlenecks are found in the downstream logistics within the BP supply chain.

11.1 Bottleneck identification

When designing a new SC an important task is to address possible bottlenecks. By identifying the weakest links it can be reinforced. Nevertheless, in accordance with the theory of constraints there will always be bottlenecks in the system, but by highlighting them the SC strategies can be outlined to avoid major problems.

11.1.1 Volume

The amount of fuel that each CHP needs is based on the required energy output, measured in Mega Watt hours (MWh). Since the calorific value of BP is lower than for coal, there will be a difference in volume required when using BP to gain the same output as if only coal were used. Table 10 shows the absolute volume difference at Reuter West for the different co-fire rates. When 10 percent of the energy generated is from BP the volume increases by 2.5 percent. At a 60 percent co-fire share of BP the volume increase is 15 percent. If only coal where to be used in 2020 the total amount needed would be about 7.85 million of ton, compared to 8.8 million when co-firing. Consequently, an additional 1 Mton of products has to be shipped in order to reach the required energy and heat generation.

Difference in volume between co-fire BP and coal and only using coal

Co-fire rate BP	Difference (ton)	Difference (%)
10%	25 721 ton	2.5 %
20%	51 443 ton	5 %
30%	77 164 ton	7.5 %
40%	102 885 ton	10%
45%	115 746 ton	11.25%
50%	128 607 ton	12.50%
55%	141 467 ton	13.75%
60%	154 328 ton	15 %

Table 10 Difference in volume between co-fire and only using coal

11.1.2 Bulk Density

The bulk density of BP is 750 kg/m^3. Bulk density for coal is around 850-925 kg/m^3. Hence BP is lighter compared to coal, meaning that it requires more space to store the same weight, adding cost per ton stored. For handling activities more time is needed to move the same weight of BP compared to coal.

11.1.3 Feedstock Availability

The capacity of feedstock may limit the production rate of BP. As mentioned, it is one of Vattenfall's major tasks to ensure the capacity of feedstock. Vattenfall's assumption is that the production plants in Liberia, British Columbia and Eastern Canada will provide sufficient and constant flows of BP in order to reach the required amount. This assumption is extended to fill any type of vessel at any quarter through the year. So, the risk of being short of supply will be neglected.

11.1.4 Production Capacity of Black Pellets

The production capacity of each plant is limited. It is therefore not possible to source from the nearest location or from the place with the lowest cost. This will influence the order size, the transportation cost and the inventory in transit cost etc.

11.1.5 Port Availability

Port availability is a major constraint to the transportation network, as it limits the size of the vessel. By limiting the available parcel size the cost for sea-transportation per unit will be higher. The depth in the port of Buchanan is 10.5 meters, which equals vessels with a deadweight of approximately 50 000 dwt. The Panama Canal limits the size of the vessels from British Columbia, to vessels of around 70 000 dwt. E.g. for Liberia the price per unit with a Supramax would be 8.4 $/ton compared to 2.6 $/ton if a Capesize was used.

11.1.6 Global Sourcing

Long distance shipments are a possible bottleneck. The sea voyage from British Columbia to Europe is around 30 days. When the lead-time is that long it is difficult to respond to variations in demand. Also, if something would happen during shipment, it would take time to replace that order. The round voyage is about 60 days, and the long distance will also increase the number of vessels needed to keep the frequency required to supply the amounts to the CHPs.

11.1.7 Handling

Handling time and cost are two of the most expensive items related to bulk material, as additional costs are added every time the commodity is moved. The amount of cargo in the system will consequently add costs. For instance, the extra volume needed will have an impact on the handling costs as the terminals charge per ton. As mentioned in the theory chapter, it is crucial to reduce the number of handling activities in the supply chain in order to reduce the overall cost. This is a possible constraint to the design of the transport corridor, such as adding a hub in order to implement the push-pull strategy.

11.1.8 Bunker

Bunker cost will have an impact on the sea transportation cost. Vattenfall cannot control this external variable, but it will influence the total transportation cost. If the future bunker cost increases over sustainable limits, the profitability gained from BP sourced from long distances may be reduced.

11.1.9 Storage Site Capacities

Black pellets can either be stored at terminals owned by Vattenfall or by a third party. The capacity is limited at the storage sites owned by Vattenfall. Additional capacity can be bought from third parties, with risk of fluctuations in price. Both coal and BP will be stored outside in separated piles. They can use the same facilities for storage. The amount of cargo that can be stored depends on the angle of repose for coal and BP respectively as well as by the number of piles that are stored. Adding an extra pile will reduce the total capacity of the storage site, thus creating a possible bottleneck.

11.1.10 Regulations

Regulations from public entities and governments regarding transportation, storage and handling may put constraints to the transportation network for BP. For instance, in the Berlin area there are timeslots for when it is allowed to discharge the cargo, which could create a conflict between discharge times for BP and coal.

Another physical constraint created by regulations, for instance whether BP must be covered during transportation or not. It is assumed that this is not needed, but if this assumption is incorrect, it may be difficult to locate carriers that fulfil those possible requirements.

BP is a non-toxic commodity; therefore we assume that the regulation will not differ from the regulation regarding coal. However, BP is an organic material whose characteristics are not completely known. So, whether regulations will create an additional bottleneck or not, cannot be said at this point.

11.1.11 Inland Transportation Providers

Third parties will provide inland-transportation and therefore additional capacity can be added without extra investments. This is an advantage when coping with variations in demand. This approach may increase the future price since occasionally added transportation capacity can be expensive to hold by third parties, as they in this case needs to hold overcapacity that are not fully utilized.

11.1.12 Barge Capacities

Capacity of barges is directly related to the capacity of the waterways. The barge size and the distance between the storage site and the CHP set the frequency of the order delivery as well as the number of deliveries needed to supply each CHP. The barge capacity to the Berlin area is 1500 dwt. This means that 643 barges are needed in 2020, (appendix 6, table 18). If the capacity of the waterway allowed barges of 3200 dwt, as in the Netherlands', only 301 barges would be required. This would reduce the inland transportation cost. This is another external constraint that Vattenfall cannot influence.

11.1.13 Seasonality

The Inland waterways freeze during wintertime, making it impossible to use barges. This occurs at the river that supplies the Berlin Area. Trains are used during those months, which is a less cost effective transportation mode compared to barges and riverboats. Also, the train capacity is smaller than capacity of barges, creating bottlenecks in the system during this season when the demand of energy has a tendency to increase.

11.1.14 Storage at CHP

The dimension of each storage site at CHP limits the capacity of holding BP as well as the dimension of the storage site at the terminal. The number of piles stored creates a severe bottleneck, as this reduces the storage capacity the most. In contrast to storage sites at the port, there is no additional storage at the CHP or terminals that can be obtained from third parties. Adding storage capacity can therefore only be obtained by investing in new storage areas. This is constrained by environmental regulations as well as public acceptance. Unknown characteristics of BP may be subject to supplemental requirements such as additional ventilation of the storage piles. These require investments but will not impact the amount of cargo that can be stored.

11.1.15 Discharging

Discharging time at each CHPs are dependent on the manpower, timeslots and space at the unloading location. For example, at Buggenum only one barge with a capacity of 2500 ton can be discharged per day. The average daily demand of BP in 2020 will be 1140 ton and 500 ton of coal. Thus, the unloading time will not cause a bottleneck. Nevertheless the margin is narrow and it will be necessary to schedule the barges to ensure a sufficient fuel supply.

11.1.16 In-House Logistics

In-house logistics mainly consist of conveyor belts that will transport both coal and BP. The main constraint of this transportation is the velocity at which the commodity is transported and the weight capacity of the conveyor belt. The conveyor belt used at Tiefstack has a capacity of 230 ton/h, whereas the average fuel demand for both coal and BP is 60 ton/h, meaning that this will not likely be a constraint in the future.

11.1.17 Mill

During the co-firing stage, coal and BP is put through a mill to be grinded into a dust before being burned together to generate heat and power. The mill capacity might be reduced when using BP. Additional adjustments to the mill will most likely be needed when co-firing BP at a high share. In worst case an additional mill will be needed.

11.1.18 Demand Fluctuations

The amounts of heat and power produced are triggered by the demand for these services from residences and industries. According to the European Commission, the future energy demand will increase. Consequently, more fuel will be needed in the system. This will create constraints and put pressure on the capacity of the transportation network. Moreover, the particular characteristics of the services, that neither heat nor power can be stored, makes it crucial to produce exactly the amount acquired. During low demand, the production utilization is kept low, while during peaks the production runs at full capacity. Demand fluctuates both over the days as well as over the seasons, making the CHP utilization vary. At imbalanced systems like this - overall inventories are increased.

12. Conclusion and Further Research

In this chapter general conclusions are drawn based upon the key findings in previous chapters. The research questions are answered followed by a discussion about which further research that can be conducted in this field.

12.1 Conclusion

Black pellets is a new fuel with the possibility to change the way of producing heat and power at dedicated coal plants. The impacts the material will have on the energy market are not discussed in this report, but the authors believe that it will create a paradigm shift that will not only change the power balance between coal producers and coal purchasers, but also influence the public's view on the production of heat and power at coal plants. We believe that BP is one contributing factor that will solve the futures' paradox of increased energy demand while reducing CO^2 emissions.

The main disadvantage with the implementation of BP is the additional volume needed to gain the same energy output as from coal. This will increase the transportation cost per MWh produced. After analysing BP we find that it is not the characteristics of the material that will create the major bottlenecks in the transportation corridor, but rather the transportation system itself that will put constraints on the supply chain. The main bottlenecks are found in the inland-transportation network; both the barge capacities and discharging time at the CHPs constrain the supply chain. Other variables that may cause problems for the BP supply chain are the long distance shipments and port availability, which influences the vessel sizes.

- How to integrate the future supply chain of BP to the existing coal supply chain?

The two products coal and BP have two different market mechanisms: coal is sourced in an open market and black pellet is produced in-house. The supply chain of coal relies in achieving high flexibility, which is done by increasing inventory levels and by relying on flexibility in both the sea transportation as well as in the inland-transportation system, which is adding costs. However, the company justifies these costs by the opportunity of purchasing coal when it is cheap.

The supply chain for BP will not strive for high flexibility as the supply chain of coal. By being able to predict the supply of BP, inventories can be kept low and the transportation network can be planned to reduce costs. When actors, like Vattenfall, invest in the whole supply chain they must be sure that the value of the product in the future is less than bought and deliver by a competitor. The logistics costs represent a high share of the total landed cost for BP, and the cost of transporting the material is added to the cost of the material. Reduction of the logistics cost will therefore reduce the total value of the product. The competitive advantage of sourcing and co-firing with BP will be gained by optimizing logistic costs.

We propose that the supply chain of coal and BP should be organized separately. As the two materials have different market mechanisms a combined supply chain would require a compromised strategy. It will however be crucial to make an additional strategy for the two supply chains, as they will serve the same propose of generating heat and power and the demand for each product will be based on the same forecast. Besides, the two materials will have to share some of the transportation assets in the system, such as storage sites, handling equipment etc.

- What strategic solutions are recommended when introducing black pellet from British Columbia, Eastern Canada and Liberia to Vattenfall's German and Dutch coal plants in the current logistic system in Vattenfall, between the years 2013-2020?

In order to reduce inventory levels we suggest a push-pull approach for BP. With the long lead-times that appear with global sourcing, it is important to lower the transportation cost per unit, which is done by using the largest vessel acceptable. The capacity of the inland transportation is lower than the capacity of the sea transportation. Consequently, it will be necessary to have a storage site at a port in Europe. It is at this point the boundary between push and pull will be located. By making the separation between the two approaches at this point, it is possible to optimize the two different capacities in the system, while reducing the overall logistic costs.

The pull approach will be used from the port in Europe. Between the hub at the port and the CHP the lead-time is reduced significantly. It will be possible to reallocate the material, with the purpose of managing variations in demand. With short lead-times the system will have better ability to respond to changes in demand, which will decrease the overall inventories in the system.

- How will these strategies affect the supply chain in terms of the design of the transport corridor, focusing on inventory levels, the overall costs and on sea-transportation alternatives?

The strategies we suggest for Vattenfall will improve the supply chain management, by controlling the levels of inventory in the system. Since it will be a continuous production flow of BP large safety stocks will be avoided.

Ports characteristics will constrain the vessel size at the port of loading. During the first years, the choice of vessel size for the sea transportation leg are not constantly based on the largest vessels possible, since both frequency of the deliveries and factors such as shipping contracts are valued higher. After 2017 there will be sufficient enough BP in the transportation system to take advantage of economies of scale, hence use the largest vessel possible to lower the transportation cost per unit. By distributing the share between voyage and time charter contracts the charterer will hedge his risk. Contract of Afreightment is a suitable contract for shippers like Vattenfall who have a secured amount of cargo to transport from one point to another. Vattenfall may have to pay a slightly higher freight rate but on the other hand the risk assortment is positive.

12.2 Generalization

The authors believe that the conclusions provided in the paper can be applicable to other industries when implementing new bulk material into an existing supply chains. The conclusions in this thesis are applicable to bulk materials and low value commodities. Therefore cargo with other characteristics may have different outcomes.

The bottleneck analysis can be used as a reference when designing global transport corridors for bulk materials, especially other biomass materials.

12.3 Further Research

This research has been conducted under assumption and estimations of BP figures and values. Black pellets characteristics are still under investigation, so it is recommended that the validation is re-evaluated once the material exists in commercial scale. In addition, some calculations are based on coal figures under the hypothesis that BP can be treated equally, however possible changes must be considered.

This study has been delimited to downstream logistics of BP. Additional studies can be carried out for the analysis of upstream logistics and the possible effects in the BP supply chain. Further research can also be conducted in order to detect changes in BP flows due to variations in demand of heat and power. In order to understand the impact of the freight rates on the shipping decision, future studies could include an in-depth analysis of the shipping market and its impact on the supply chain.

The suggested and calculated global transportation corridor can be investigated further to include alternative routes such as trains through Canada and storage sites outside Europe.

Appendix 1 Total Annual Costs - Recommendations

Total Annual Costs – Author's recommendations *

Year	Total no. Sea vessels	Sea Transp. Cost €	Inland Transp. Costs €	Inventory Cost €	Order cost €	In-transit inventory carrying cost €	TAC (€)
2013*	**EC -7 Panamax to ARA** **EC - 1 Handysize to ARA**	**4800671**	**6637914**	**455000**	**8000**	**112000**	**12 013 585**
Optional	EC - 3 Capesize	2665046	6637914	1225000	3000	42000	10 572 960
2014*	**EC - 7 Panamax to ARA** **BC - 4 Panamax to HB**	**11153781**	**9088430**	**490000**	**11000**	**154000**	**20 897 211**
Optional	EC - 3 Capesize to ARA BC - 4 Panamax to HB	9454088	9088430	805000	7000	98000	19 452 518
2015*	**EC - 6 Panamax HB** **EC - 1 Panamax to ARA** **BC - 8 Panamax to ARA**	**17857187**	**13156889**	**490000**	**15000**	**210000**	**31 729 076**
Optional	EC - 3 Capesize to ARA BC - 6 Panamax to HB BC - 2 Panamax to ARA	16172607	13156889	690455	11000	154000	30 184 951
2016*	**EC - 4 Capesize to ARA** **BC - 9 Panamax to HB** **BC - Panamax to ARA**	**23814736**	**8919142**	**686000**	**14000**	**196000**	**33 629 879**
2017*	**EC - 6 Capesize to ARA** **BC - 15 Panamax to HB**	**32253427**	**10286457**	**700000**	**21000**	**294000**	**43 554 884**
Optional	EC - 14 Panamax to ARA BC - 1 Panamax to ARA BC - 15 to HB	35850384	10286457	490000	30000	420000	47 076 841
2018*	**EC - 7 Capesize to HB** **BC - 4 Panamax to HB** **BC - 15 Panamax to ARA** **Lb - 20 Supramax to HB**	**45100931**	**12725981**	**594028**	**13000**	**182000**	**58 615 940**
Optional	EC - 18 Panamax to HB BC - 2 Panamax to HB BC - 16 Panamax to ARA Lb - 20 Supramax to HB	48576373	12725981	451111	36000	504000	62 293 465
2019*	EC - 9 Capesize to HB BC - 22 Panamax to ARA Lb - 20 Supramax to HB	58609918	15785134	564804	51000	714000	75 724 856
Optional	EC - 22 Panamax to HB BC - 22 Panamax to ARA Lb - 20 Supramax to HB	64555841	15785134	446250	64000	896000	81 747 225
2020*	EC - 12 Capesize to HB BC - 4 Panamax to HB BC - 23Panamax to HB Lb - 10 Supramax to HB	63102637	19544641	544576	59000	826000	84 076 854
Optional	EC - 29 Panamax to HB BC - 23 Panamax to HB Lb - 10 Supramax to HB	77600817	19544641	412222	72000	1008000	98 637 680

Formulas;

The total annual cost (TAC)

TAC=$\frac{1}{2}$QS + A$\frac{R}{Q}$ + $\frac{t_m}{t}$QVW + Transportation cost

Inventory Carry Costs = $\frac{1}{2}$QRW

Order Costs= A$\frac{R}{Q}$

In-Transit Inventory Carrying Cost = $\frac{t_m}{t}$QVW

Transportation cost = Sea transportation cost + Inland Transportation costs

Sea transportation[1] = Sea freight rate *Lead-time+ Bunker Cost+ Panama Canal Tool

Inland transportation cost[2] = Cost/ton for each CHP * R

- R= annual demand for period (units)
- Q= quantity ordered lot size (units)
- A= cost placing an order or set up cost (€ per order)
    - = 1000 €
- t = Order cycle time
- t_m= Lead-time
- V= value or cost of one unit of inventory (€ per unit)
    - = 140 €
- W= carrying cost per € value of inventory per year (% of product value)
    - = 10%
- S= VW= storage cost per unit value per year

N.V. Due to confidentiality the demand of BP for each CHP cannot be displayed

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[1] Appendix 2

[2] Appendix 3

Appendix 2 Sea transportation cost

Sea Freight Rate

Sea Freight Rate T/C Price

Vessel size	$/day	€/day
Handysize	10519 $	15581
Supramax	13175 $	19516
Panamax	13581 $	20117
Capesize	14300 $	21182

Bunker costs

Bunker cost per ($/day)

Vessel size	HFO Ton (loaded)	HFO ton (empty)	MDO berth ton/day	Panama Canal $*
Handysize	15500	12400	3732	111860
Supramax	23325	15500	3732	142772
Panamax	22750	18600	3732	207172
Capesize	37200	31000	3732	

Bunker type	Bunker Price ($)	
HFO	620	*16 May 2011
MDO	933	*16 May 2011
LHFO	650	*16 May 2012

Panama Canal Toll

Panama Canal Tool 2011 Cost / Vessel Size

		Full vessel			Ballast			Total
	Gross ton	1st 10K	2nd 10k	> ton	1st 10K	2nd 10k	> ton	
Handysize	25000	37300	36500	17950	2960	2900	14250	111860
Supramax	29800	37300	36500	35182	2960	2900	27930	142772
Panamax	39800	37300	36500	71082	2960	2900	56430	207172

* Panama Canal toll, excluding extra costs for brokers and additional charge (Panamá 2011)

Lead-time for Loading and Discharging + Extra Days at Sea

Loading/Discharging LT (days)

	Handysize	Supramax	Panamax	Capesize
Loading	4	4	5	6
Discharging OBA	3	3	4	6
Discharging HB	3	3	3	3
Extra day at the sea	3	3	3	3
Total Netherlands	10	10	12	15
Total Germany	10	10	11	12

Lead-time Sea Transportation

Lead-time (round trip)

From-To / Vessel size	Handysize	Supramax	Panamax	Capsize
EC- ARA	28	28	30	33
EC – HB	30	30	31	35
BC-ARA	70	70	72	75
BC-HB	72	72	73	74
Liberia-ARA	31	31	33	36
Liberia-HB	33	33	34	35

Value of the product and dollar convention

Additional Information

Value of the Product €	Dollar convention
140	1 Euro = 1.4813 U.S. dollars

Appendix 3 Inland transportation

Inland Transportation Network

Inland transportation network

European Hub	CHP	Cost (€/ton)	Capacity (ton)	Storage cost (€/ton)	LT (days)
Hamburg	Moabit	12	1500	0,06	3
Hamburg	Reuter W	12	1500	0,06	3
OBA	Reuter W	30	1500	0,06	7
Hamburg	Reuter	12	1500	0,06	3
Hamburg	Tiefstack	2.5	3000	0,06	1
Hamburg	Moorburg	0		0,06	
OBA	Hemweg	2.12	24 000 (ton/day)	0,06	1
OBA	Buggenum	5.12	3200	0,06	2

Number of barges per year to each CHP

Number of Barges per Year to each CHP

CHP / Year	2013	2014	2015	2016	2017	2018	2019	2020
Moabit					26	39	52	78
Reuter West	129	171	257	343	343	429	514	643
Reuter				14	29	57	57	86
Tiefstack				29	39	59	78	118
Moorburg								
Hemweg	21	27	41	55	69	69	96	49
Buggenum	28	56	46	74	93	93	130	130

Frequency of barges per month

Frequency of Barges per month

CHP/ Year	2013	2014	2015	2016	2017	2018	2019	2020
Moabit					2	3	4	7
Reuter West	11	14	21	29	29	36	43	54
Reuter				1	2	5	5	7
Tiefstack				2	3	5	7	10
Moorburg								0
Hemweg	2	2	3	5	6	6	8	4
Buggenum	2	5	4	6	8	8	11	11

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