CHALMERS

Evaluation of Business Opportunities for Alfa Laval
Regarding Heat Recovery and Mist Elimination of Flue Gases

Master of Science Thesis in Management and Economics of Innovation

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Göteborg. September, 2010

Sebastian van Reis

Fredrik Samuelsson

EXECUTIVE SUMMARY

The focus of this master thesis lies within flue gas treatment at power plants with an effect of 0-30 MW. The thesis has been conducted on behalf of Alfa Laval AB, a world leading company within heat transfer, separation and fluid handling. As an effect of being a large organization in combination with having an innovative history, Alfa Laval is continuously searching for new market and business opportunities. Given that flue gas treatment is closely related to the core competence and capabilities of Alfa Laval, the setting of this master thesis was originated as the result of a brainstorming meeting with the purpose to discover new business opportunities, building upon already established competencies.

The purpose of this master thesis therefore is to investigate potential business opportunities for Alfa Laval in terms of heat recovery and mist elimination of flue gases from boilers.

The thesis follows an iterative structure where relevant theories are reviewed prior each new chapter. Inputs for the empirical context and background are gathered through in-depth interviews with: potential buyers, competitors, technical experts, institutes, universities and several employees within Alfa Laval as well as publications from governments and institutions such as the EU-Commission, US Environmental Protection Agency (EPA) and the Central Intelligence Agency (CIA).

The result of this master thesis confirms that the flue gas treatment market is attractive for Alfa Laval. It moreover identifies several resources and capabilities, both internal and external, which can be used to grasp potential business opportunities on the market. However, the major finding of the thesis is that centrifugal separation of gases, which already is, a technology in use within Alfa Laval, could be deployed in order to separate the particles in flue gases. Centrifugal separation would be a challenging substitute to the established and dominant filtration techniques on the market today. Centrifugal separation of flue gases would furthermore create a sound business opportunity as it reduce investment cost by 50%, require 80% less space when installed and substantially less maintenance costs compared to the filtration techniques. A rough estimation shows that centrifugal separation of flue gases could increase Alfa Laval's invoices with about 600 MSEK annually.

The recommended action for Alfa Laval is to grasp the opportunity to enter the market of flue gas treatment using the centrifugal separation technique. This would favorably be done by an acquisition of the small competitor 3nine, which resources should be integrated into Alfa Laval's organization. Integrating 3nine into Alfa Laval's organization would most plausibly generate positive synergies while at the same time avoiding common pitfalls and inertia that are present in large companies when developing new technology internally.

WORDLIST

Core competence - Specific factors that a company considers central to the way it, or its employees, works.

Particles - Tiny subdivisions of solid or liquid matter suspended in a gas or liquid.

Installed base – A Measure of the number of units of a particular type of system actually in use.

Microns - One millionth of a meter and has the prefix µm.

Overheater - Overheats the steam in a boiler system to reduce the energy consumption.

Economizer - A heat exchanger that recovers the heat from the boiler's flue gas and transforms the heat to the boiler's feedwater.

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1 Introduction

In this initial chapter, a brief description of the master thesis at hand is provided together with a short introduction of Alfa Laval AB. The introduction starts with a description of the background of the thesis, which provides the reader with an underlying understanding of why Alfa Laval is interested in entering a new business domain. The background is followed by the purpose of the thesis, with assigned research questions and delimitations as well as information regarding how confidentiality is handled. The introduction chapter ends with an outline of the thesis.

1.1 Background

Mist elimination from various types of industries has been under the loop since the 1970´s. Emissions as well as pollutions from electricity generation have particularly been controlled due to their high volumes as well as the combustion of fossil fuels. For the producing companies, the emissions furthermore create negative public relations which in turn can have negative effects on the companies' businesses and related activities. Even due industry specific emissions have decreased heavily during the 1990´s, mist elimination techniques has more or less stagnated since the end of the same decade, resulting in maintained emission levels during the 2000s, see *Figure 1*. (Ekonomifakta, 2010)

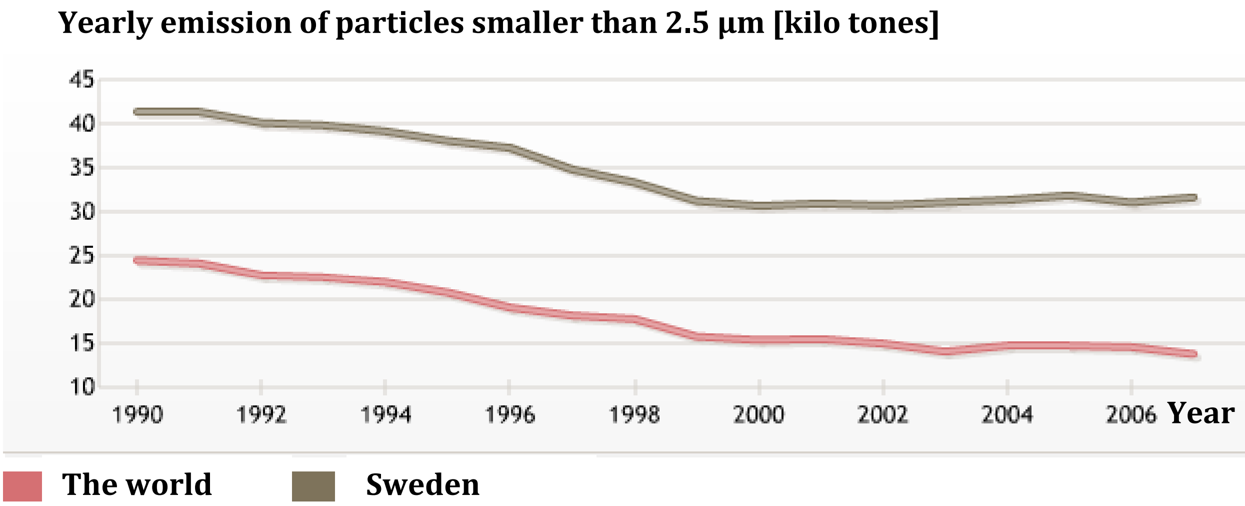

Figure 1. Yearly emissions of particles between 1990 and 2006

Even if the development of mist elimination has somewhat stalled during the 2000s, the opposite applies for the prices of electricity. The prices on the electricity market have during the last couple of years had an increasing trend (European Comission, 2010) and the need to make electricity generation more effective is more important than ever. Furthermore, since the electricity market is vast, even small contributions regarding the level of efficiency would create sound business margins.

This thesis is written on behalf of Alfa Laval AB. Alfa Laval is a Swedish based company, founded in 1883, with a world leading position in specialized products and solutions for heating, cooling and separation. Alfa Laval's core competencies lie within heat exchange, separation and fluid handling. In terms of heat exchange techniques, Alfa Laval has primarily focused on plate heat exchangers while they use centrifugal separators in terms of separation. During brainstorming meetings regarding new business possibilities at Alfa Laval, the idea awoke to combine two of their core competences into a system solution for heat recovery and mist elimination of flue gases from the combustion processes at power plants. With an outspoken mission to optimize the performance of their customers' processes, time and time again, Alfa Laval has since 2004 increased their spending on R&D and new innovations with 78% to 718 million SEK. Therefore, with such ambitious and innovative spirit, it falls naturally for Alfa Laval to constantly seek new business opportunities and new business domains.

As power plants and especially the flue gases from the combustion processes falls outside the core business and knowledge of Alfa Laval, further studies were required in order to evaluate the potential market and form a decision basis to either develop products and solutions for the new business domain or not. Both the existing market and the existing products and solutions needed to be investigated. Furthermore, Alfa Laval's resources and capabilities needed to be mapped out in order to decide if any of these could be used in a new potential business domain. The task of conducting these further studies was assigned to Chalmers University of Technology.

1.2 Purpose

The purpose of this master thesis is to investigate potential business opportunities for Alfa Laval in terms of heat recovery and particle separation of flue gases from boilers.

1.3 Research questions

In order to obtain the purpose, this master thesis aims at answering the four research questions provided below:

1. What does the market characteristics look like in terms of competition, technical solutions and legislations?

2. What internal resources and capabilities does Alfa Laval possess that can be used or developed in a potential system solution for flue gas treatment?

3. Are there any potential business opportunities for a combined system solution of heat recovery and particle separation of flue gas for Alfa Laval?

4. Given that there is a business opportunity, how should Alfa Laval strategically exploit such an opportunity?

Each of the first three research questions correspond to one of the cornerstones illustrated in *Figure 2*. The first cornerstone; "Market", is dealt with in chapter 4 and aims at answering the first research question. By studying the internal resources and capabilities of Alfa Laval in chapter 5, the intersection of the two cornerstones will provide an answer to research question 2. In chapter 6, the scope will be narrowed down even further by investigating which, if any, of the resources and capabilities of Alfa Laval that could become a business opportunity with a sound business model within the given scope. An investigation of the intersection between the three cornerstones will answer the third research question. Moreover, chapter 7 aims at investigating how to exploit the business opportunity, given that there is such an opportunity.

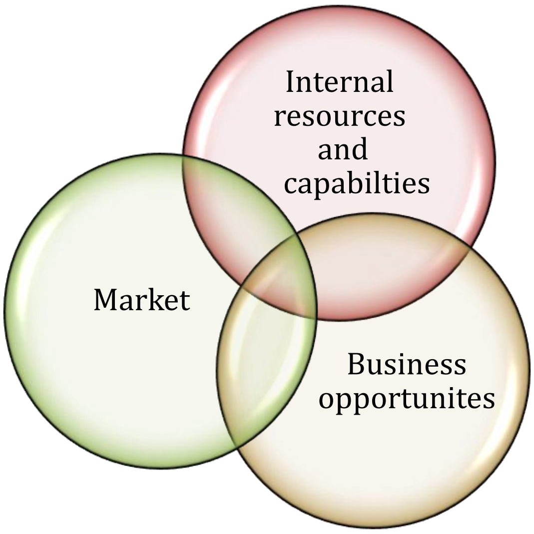

Figure 2. The scope of the master thesis

1.4 Delimitations

Due to limitation in time, the study of this report only comprehends the technical aspects of the boilers, complementing products and solutions as well as the system solutions to the extent that is for creating fundamental understanding of the boundary conditions and the knowledge required to perform a commercial analysis. Moreover, as some of the analyzed business opportunities are built on future and unreleased products of Alfa Laval, the analysis mainly concerns qualitative approach in order to avoid numerical and precise calculations of highly speculative and approximate data.

In terms of emissions and mist elimination, the report only focuses on particles. Other emissions such as the greenhouse gases (CO_2, N_2O, CH_4 et cetera) are handled in other projects at Alfa Laval dealing with carbon capture, and are therefore left outside the scope of this report.

The boilers and the processes there within are in this report considered as a closed circuit that have been optimized, using millions of engineering hours since the origin of the steam boiler in the eighteenth century. Potential improvements of the boiler's process during a master thesis with a time limitation of 20 weeks could be considered negligible, if not impossible to accomplish. Therefore, the report only focuses on flue gases leaving the boiler process on its way to the chimney.

The report is moreover limited to boilers combusting biomass, waste and coal. Oil, natural gas or other types of fuel are not dealt with in this report. However, the results provided in this report might also be applicable to some of these fuels with some modification, depending on the boundary condition of the system solution.

1.5 Confidentiality

Due to strategically sensitive issues concerning future or unreleased products and solution within and from Alfa Laval AB, the final report will be written in two versions; one to be delivered to Alfa Laval and the Chalmers supervisor, and one public version to be published. The public version is censored from sensitive data to an extent required by Alfa Laval.

1.6 Outline of the thesis

The outline of this master thesis is of an iterative type. In contrast to a typical master thesis that starts with a literature review ends with a discussion, the thesis is divided into several chapters which all include their own literature review, empirical input and analysis, see *Figure 3* below.

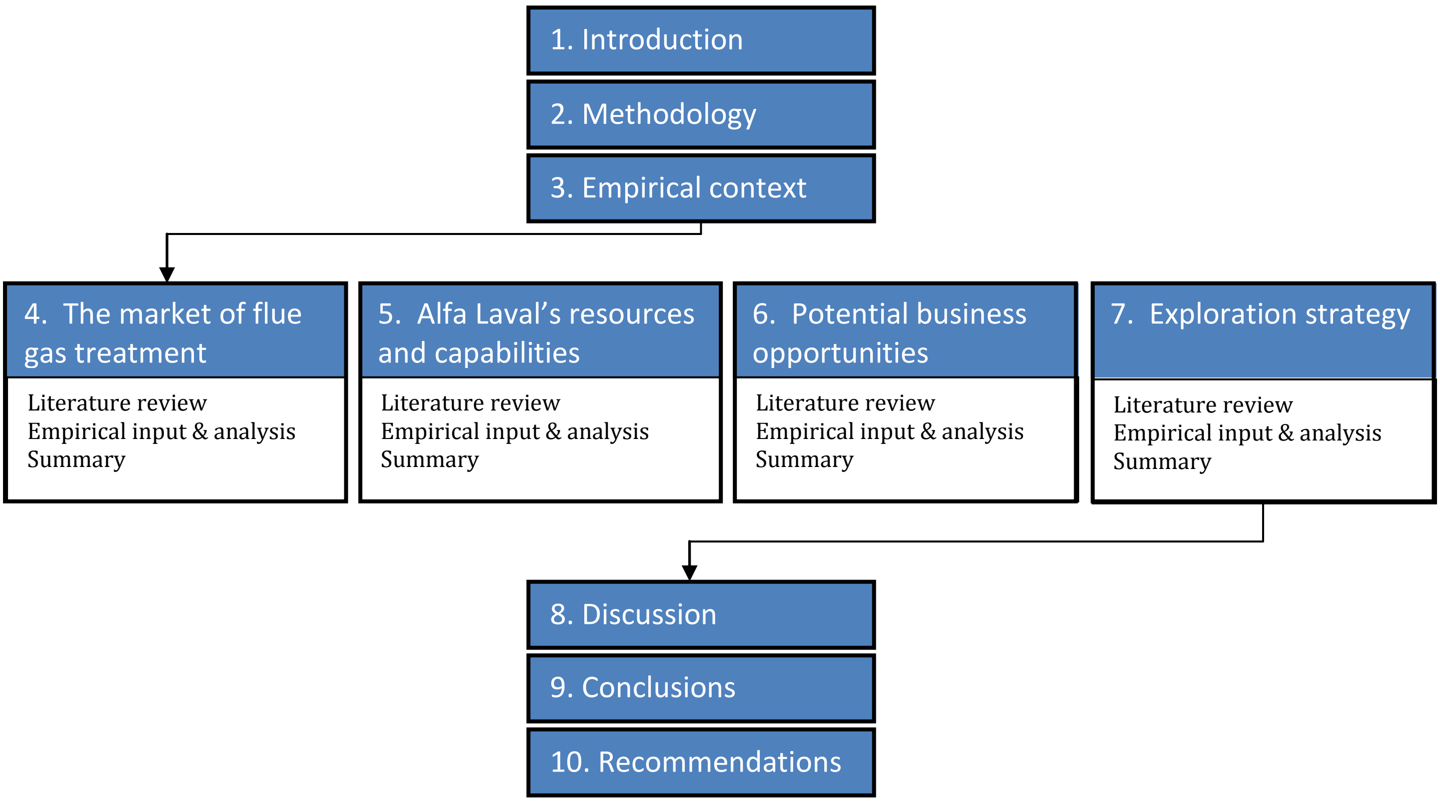

Figure 3. Illustration of the report's outline

The report starts with an introduction chapter, providing a general overview of the report, the purpose, the research questions and its delimitations. The introduction is followed by a methodology chapter that applies for the whole report. The methodology chapter is in turn followed by an empirical chapter that provides the context as well as background information regarding the market.

Thereafter, four chapters all aiming at answering one of the four research questions are provided. Each of these four chapters does furthermore correspond to either a cornerstone in *Figure 2* or one of its intersections. Thereby are each of these chapters also tightly connected to the findings and analyses of their preceding chapter. The first of the four chapters investigates the market for flue gas treatment. The second one investigates Alfa Laval's resources and capabilities in relation to the flue gas treatment market. The third one analyze if there are any potential business opportunities given Alfa Laval's resources and capabilities, and the final of the four chapters analyze how such a business opportunity should be strategically exploited.

Finally, a discussion as well as the conclusions and recommendations are presented followed by suggestions for further investigation and the appendices. The appendices contain valuable information and statistics which were overly lengthy to present in the report. Furthermore are diagrams and data, which have been of secondary importance, also represented in the appendices. These data, statistics and diagrams are presented in order to ensure the transparency of the report.

2 Methodology

In this chapter, the research design and methods used for data collection are described. The thesis has a practical oriented outcome with the objective to evaluate Alfa Laval's potential in a new business domain. This requires an understanding and knowledge regarding the industry and how it works in order to evaluate if Alfa Laval's techniques would function on that market. For this objective a multi-strategy research method is employed using mixed methods that combine a quantitative and a qualitative research approach as suggested by Bryman & Bell (2007).

In order to accomplish a broad overview and at the same time being able to evaluate new technologies, three main categories of sources have been used for the collection of data. The three categories are; *literature reviews*, *internal interviews* and *external interviews*. Both the internal and external interviews contribute with primary data, while the literature review contributes with secondary data. Moreover is the internal interviews performed within Alfa Laval while the respondents of the external ones are competitors, potential customers as well as other key players on the market. Each of these categories is described in an own section along with its related pitfalls. However, the overall research quality issues are covered lastly.

2.1 Secondary analysis

Secondary analysis deals with data not collected by the researcher and most likely not collected for the purpose of the study at hand (Bryman & Bell, 2007). The secondary data used in this thesis comes from articles, books, websites and publications.

The purpose of the collection of secondary data through a literature review is to obtain a general understanding of the industry as well as knowledge regarding how current technologies work. Without the information provided by the secondary data, the boundary conditions of the market could not be set and new technologies could not be investigated in relation to the existing ones. The information found through secondary data collection partly provided the basis for chapter 3, 4 and 5 as well as crucial inputs when evaluating new technologies.

2.2 Literature review

By reviewing existing literature within the topic of this thesis, a fundamental understanding of the industry is provided. The literature review did also unfold some of the most common technologies and their purpose. Initially all interesting books and articles with specific keywords where skimmed through critically and evaluated for the relevance of the thesis. Extensive notes were also taken to simplify the writing of the report, as recommended by Bryman & Bell (2007).

The amount of available information through library databases and books are vast, thus only including relevant information was of outmost importance. Moreover, is not only new literature of interest as many old boilers still are used within the industry. These old technologies are important as they constitute a market for retrofit kits and thereby make old literature such as for instance books, articles and periodicals useful as well.

There is however always a risk of some literature being biased, for example by being written, sponsored or encouraged by an industry player. Bryman & Bell (2007) state that an indicator regarding the quality of, for instance an article, is if the journal in which it is published in is well renowned. Although, this is not a panacea whereby the sources of the literature used in this thesis has gone through critical inspection before adoption. To critically inspect the bibliographies of interesting publications is according Bryman & Bell (2007) a useable method in order to reduce the risk of biased literature.

2.3 Primary data

The lion share of collected data used in this thesis relies upon primary data. The external primary data was first of all used in order to map the industry, technologies and the market while the internal primary data was used in order to map Alfa Laval's resources and capabilities. In appendix II a full list of both the internal and external interviews performed is provided. Below follows a general description of the primary data collection of this master thesis, followed by separate sections covering special considerations for the internal and external data collection respectively.

This thesis' primary research method consists of interviews that capture information in a coherent and cohesive way. The interviews has been performed both face-to-face as well as by telephone. Bryman & Bell (2007) states that some interviewees feel threatened and unsecure by recording equipment in an interview situation, and might hesitate to participate or provide information if such equipment is used. Based on recommendations provided by Bryman & Bell (2007), the interview recordings has been captured by paper and pen by both interviewers and later compared in order to avoid misunderstandings or misinterpretations.

Bryman & Bell (2007) moreover state that there are many different types or styles of research interviews such as structured, unstructured, semi-structured and so on. In qualitative research the two main types of interviewing styles are semi-structured and unstructured while structured interviews often are utilized in quantitative research. In the qualitative research of this study a semi-structured interview style has mainly been employed. An advantage of the semi-structured interview style is that the research situations and the collected data will reflect differences among the interviewees rather than the different interview situations, and thereby be more applicable for comparison (Flick, 2008). The semi-structured interview uses a list of questions on specific topics often referred to as an interview guide. The guide does not have to be strictly followed which makes the interview process flexible regarding which questions that are asked and in what order (Bryman & Bell, 2007). The semi-structured style does furthermore provide the interviewer with a possibility to add questions if new interesting subjects is brought up. The used questions shall however be similar from interviewee to interviewee (Bryman & Bell, 2007).

Furthermore, a semi-structured interview style is in this thesis favorable compared to an unstructured interview style based on several aspects. First, the semi-structured interview-style is better in order to ensure comparability that makes it possible to link differences and similarities between interviewees. Secondly, if there is more than one person interviewing, all interviewers can have a more active role using the semi-structured interview. Thirdly, there is a clear idea of how the data will be analyzed and more specific questions can be developed during the interview procedure using a semi-structured interview style (Bryman & Bell, 2007).

Moreover, several interview guides have been used in the thesis to cover the different aspects of the study. Before being adapted, each guide has been subject to change after been tested and validated on an available population of fellow students.

When preparing the interviews, there are a number of issues that need to be considered. It is important to get familiar with the settings where the interviewee is active, to ease the understanding of the response. To encourage and motivate the respondent to participate in the interview it is good to quickly establish a relationship with the interviewee. Moreover is it important that the language used during the interview is comprehensive and easy to understand as well as asking questions in a logical order (Bryman & Bell, 2007). All these issues have been focused upon and addressed during the primary data collection of this master thesis. Furthermore has biased or directed questions been avoided as these can have a negative effect on the quality of the answers (Wilkingson & Birmingham, 2003).

During the course of this thesis the authors have to some extent acted as participant observers by being members of the social settings at Alfa Laval. This made it easier to understand the interviewees as participant observers are more likely to obtain information that the respondent takes for granted (Bryman & Bell, 2007). However, in such situations, the researcher needs to be aware of the potential drawbacks that can arise. One such potential drawback is that the researchers risk losing their sense of being researchers and become wrapped up in the world of the persons they are studying by *going native* (Bryman & Bell, 2007). This phenomenon that arises from being immersed in the organization during a long period of time has been minimized by compiling the final report outside of Alfa Laval.

2.4 Internal data collection

The internal data collection refers to interviews conducted internally at Alfa Laval. These interviews could easily be subjective to going native, as described earlier. Issues of prestige can also affect the respondents regarding their tasks and knowledge. Then there is a risk of the respondent exaggerating certain aspects that are within the respondent's area of expertise in order to highlight his/her importance to the firm. Such problematic needs to be considered carefully as the interview otherwise risk being biased (Bryman & Bell, 2007). In this thesis, these issues have been avoided by triangulation of research methods in use whenever considered possible.

The reasons for conducting the internal interviews have been to get information about Alfa Laval's resources and capabilities as well as strategy and structure. Such information could have been collected much quicker by a person working at Alfa Laval, with previous experience at hand. However, because of earlier failures in similar projects, the need for knowledge from more than one division and the fact that the investigated business opportunity lays outside of the present organization boundaries, an outsiders view was needed[1]. Such a view would not as easily get stuck into present structures and indoctrinated organizational values.

2.5 External data collection

The collection of external data refers to, as mentioned earlier, interviews conducted with potential customers, experts at institutes and competitors externally related to Alfa Laval and the market for flue gas treatment.

To gain access to people outside of the sponsoring organization can be difficult according to Bryman & Bell (2007). They also state that resistance and tentativeness can be expected from external respondents. In order to facilitate the tentativeness and limit the resistance, meetings should preferably be arranged at a convenient time for the respondent and interviewers provide well structured interview guides prior the interview (Bryman & Bell, 2007). This strategy has in this thesis been carefully adopted, as both external and internal interviewees have gained access to the interview guides prior each interview as well as to a large extent been able to influence the time and dates for every interview.

Furthermore, the respondent from an external organization might be unwilling to provide the whole truth. Once again it is important to quickly establish a relationship with the respondent to resolve this issue. Bryman & Bell (2007) state that if only a single person in a company is interviewed, this person could describe its own area and position in the company as more favorable than it actually is. To deal with this issue more than one person at a company has to be interviewed when possible. The issue regarding occupied work time is probably even more impacting in terms of external interviews. To mitigate this issue and to get rich answers, contacts within AlfaLaval have been used when possible as well as multiple interviews.

[1] Tommy Norén Manager Technologies Alfa Laval, personal interview on the 6th of Jan. 2010

2.6 Sampling process

The process of selecting suitable respondents for a study is an important issue as these often contribute to the final conclusions and thereby the quality of the report. There are a handful of different sampling procedures such as probability sampling, non-probability sampling, population sampling et cetera. (Bryman & Bell, 2007)

As the market for flue gas treatment is new to Alfa Laval as well as characterized by competition, the snowball sampling procedure has been adapted. Snowball sampling uses the acquaintances and relationships of existing study subjects in order to gain access to new ones. This method is highly effective in order to gain access to unknown or hidden populations which the researchers otherwise would have difficulties to reach. (Bryman & Bell, 2007)

2.7 Overall research quality

In order to assure a high research quality, the criteria of reliability, replication and validity are adapted. These are the most useful criteria for evaluating business and management studies accordingly to Bryman & Bell (2007).

Reliability concern whether or not the results are repeatable (Bryman & Bell, 2007). This is very similar to the criteria of replication, which concerns whether it is possible to perform the study again, i.e. if a researcher has spelled out his or her procedures in great detail. The reliability of this study is managed through rigorous use of references as well as transparency in terms of the statistics and data used. Moreover are used data and statistics thoroughly illustrated in appendences when considered necessary. All publications and data used in this study are furthermore handed over to Alfa Laval as the thesis is completed. In this way, Alfa Laval could at anytime choose to go through the data once again and repeat the process of the study. In terms of replication, the vast methodology chapter of this thesis is provided in order to ensure the reader of what methods that has been used as well as the reason why they have been chosen. Studies concerning time dependent business opportunities are however always hard to exactly replicate later on due to the changes of the paradigm.

Validity concerns the integrity of the conclusions that are generated from a piece of research. Validity could moreover be divided into five categories, namely; construct validity, internal validity, external validity, content validity and face validity (Bryman & Bell, 2007). A clarification of each validity type is provided in the list below:

Construct validity:	Does the study accurately represent the reality?
Internal validity:	Is it possible for causal relationships to be determined?
Content validity:	Is adequate coverage of the studied subject being provided?
External validity:	Is it possible to generalize the conclusions?
Face validity:	Does the result and conclusions of the study work?

Starting with construct validity, this thesis is built upon a vast empirical chapter which in turn is based upon reliable sources gathered by the qualitative research methods described above. This approach has enabled the thesis to provide a reliable and accurate representation of the reality.

Using the snowball sampling method does increase the risk of causal relationships. However, in order to avoid such relationships, all used data has been triangulated when ever considered possible in order to strengthen the internal validity. One such example is the use of internal interviews, external interviews and literature publications in the empirical chapter.

Content validity is always a little bit tricky as the apprehension of what is considered an adequate coverage is relative from person to person. Although, given the scope of this master thesis, a vast coverage of the background and the market as well as of Alfa Laval's resources and capabilities, from strategy down to product level, is provided. In relation to the boundaries of the thesis, the content validity could therefore be regarded as strong.

In terms of generalization, the thesis is restrictive. As the main focus is directed against Alfa Laval and their potential business opportunities, the thesis could be considered a case study. However, this study in comparison with a pure case study provides a broader perspective and some generalizations can therefore be made. Although, all generalizations of this thesis are explicitly highlighted, and demands backing of several independent sources.

As the study if this thesis uses a rigorous amount of sources and references, and thereby make it possible to adapt triangulation of the research methods, the result of this thesis could be considered accurate and thereby provide a sound face validity. Moreover are the analysis of the study built upon strongly validated theoretical frameworks and models.

As can be deduced from the different types of validity, the general validity of this master thesis is strong. The strong validity in combination with a distinct reliability and the possibilities of replication creates a solid overall research quality.

3 Empirical context

This initial empirical chapter will provide a description of the technologies at place. It will begin with a basic overview of a typical boiler and the systems surrounding it, in order to create a fundamental understanding of the processes. The description of a boiler system is then followed by the impact of the fuels combusted in the boiler, and how the choice of fuel affects the technologies at hand for heat recovery and mist elimination. Finally, a rough estimation of the market is provided together with some general trends for the industry.

3.1 Description of the boiler system

There are an abundance of different boilers on the market today. Haycock boilers, fire-tub boilers, water-tube boilers or flash boilers do all have their own unique purpose, but the logic behind the combustion process and the general appearance of the boilers are more or less the same.

As *Figure 4* below illustrates, the boiler consists not only of a combustion chamber but rather a whole system of several key components.

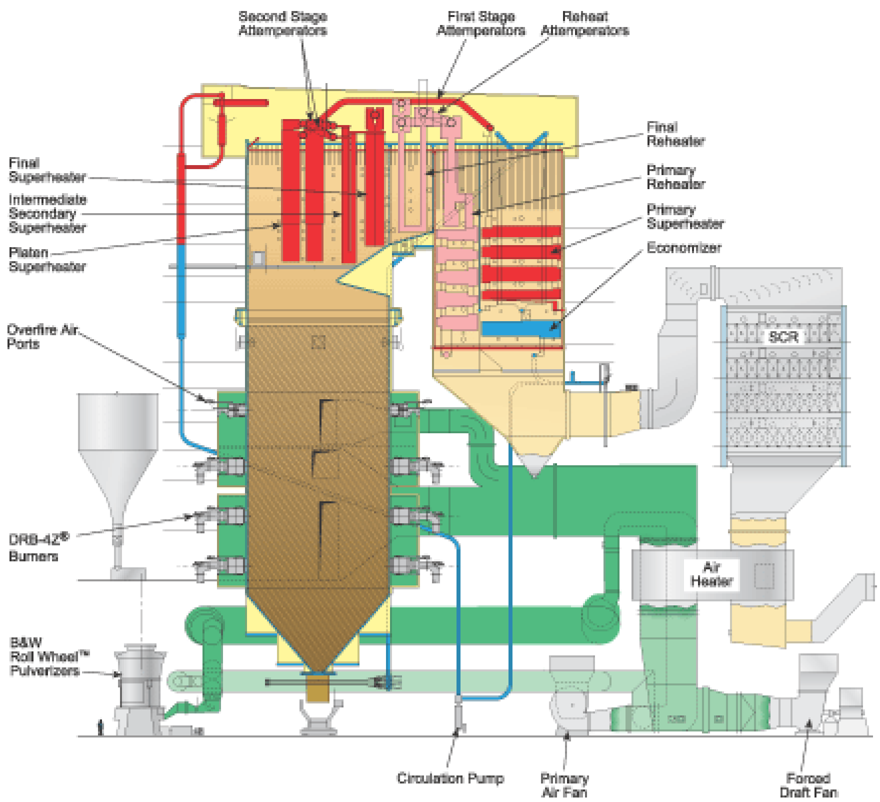

Figure 4. Exploded view of a typical Spiral Wound Universal Pressure boiler

Regardless if it is an energy plant, thermal station or a combined power and heat plant, the purpose of the combustion within the boiler is to transform water into hot steam. The hot steam could then be used either to; produce electricity in a energy plant using a steam turbine and a generator, produce heat by simple using the hot water and the hot steam in a thermal power plant or combinations of them both which normally is the case now a days.

All types of boilers have three things in common, see *Figure 5*: (1) the combustion chamber, were the fuel is combusted, (2) the water chamber, which more or less often fully covers the combustion chamber and (3) the steam chamber were all the steam is gathered. The steam chamber is moreover often located above the water chamber due to the laws of nature, as hot steam prefers to travel upwards. Notable is also the exciter room which is located in between the water chamber and the steam chamber with the single purpose to control the volume and balance between the two mediums. (Ulvås, 1969)

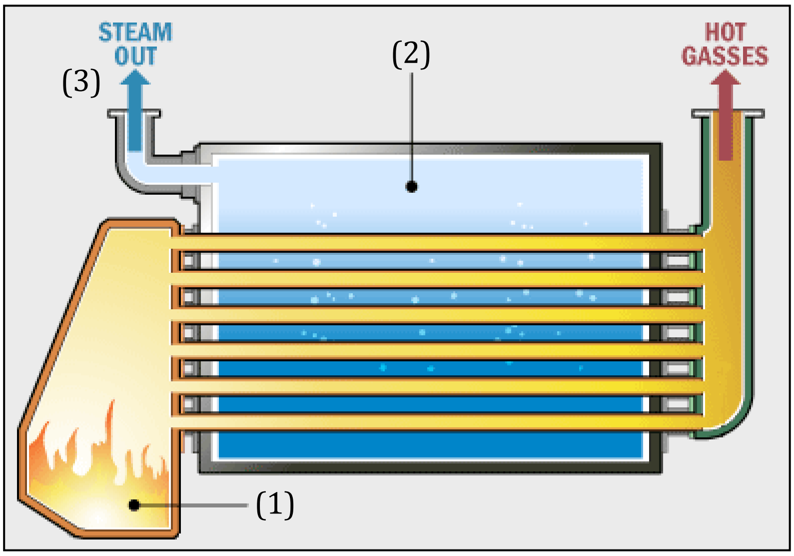

Figure 5. A simplified illustration of the combustion chamber in a roast boiler

The overall process of a steam boiler could be explained as following: The fuel in combination with a proper amount of combustion air is injected into the combustion chamber, were the fuel is lighten and burned. From the combustion process, hot flue gases are obtained which are directed through heat channels towards the chimney. As the hot flue gas is travelling through the heat channels it radiates heat to the neighbouring surfaces, in this case the water chamber. In this way, the heat from the flue gas is exchanged to the water, a process which is so refined that only a few degrees are lost in the heat exchange between the two mediums. The aim for a steam boiler is to supply a specific amount of steam per hour, at a specific level of pressure with a predefined temperature. These three parameters are therefore crucial for the boiler's dimensioning and construction. (Ulvås, 1969)

Since the flue gas can withhold temperature around 600-700°C from the combustion chamber and water only can be heated up to about 100°C, the flue gas is still very hot even after the initial heat exchange. Therefore, in order to save energy, the hot flue gas is directed through an *economizer* which semi-detached to the boiler. The economizer consists of pipes in which the feeding water, to the water chamber, runs through. As the hot flue gas passes outside of the pipes, the feeding water's temperature increases. The economizer is constructed to provide feeding water with a temperature just below the boiling point. In this way, the water inside the water chamber is pre-heated, and thereby in need of less energy from the boiler in order to transform into steam. (Ulvås, 1969)

Within the boiler system, the economizer is followed by an *overheater*. The overheater overheats the steam in a similar manner as the economizer heats the water. Overheating the steam is essential as it would be harmful for the system if the temperature of the steam would decrease below the dew point and condense. If the steam would condense, there is a threat that the whole boiler will corrode. (Ulvås, 1969)

After the flue gas has been used in order to increase the temperature of the feeding water and overheat the steam, it withholds a temperature of about 200°C as is leaves the system. This rather high temperature is once again chosen in order to avoid creating a corrosive environment. (Ulvås, 1969)

3.2 Different techniques for separation of particles

For all modern boilers, a particle separator is required in order to separate dust and larger particles. There are a handful of different alternatives for particle separation such as cyclones, electric filter, fabric filter, wet separation or sedimentation tanks at hand which all are used in different extent depending on the size and fuel of the boiler. (Ulvås, 1969)

Sedimentation Tank: In *Figure 6* to the right, a typical sedimentation tank is illustrated. Sedimentation tanks are the least complex technique in terms of dust and particle separation. The sedimentation tank is a water filled tank which the flue gas passes through in its way to the chimney. The dust and particles are separated from the flue gas simply by sinking to the bottom of the tanks due to the laws of nature. The dust and particles will then be cleaned in combination with the smudging of the boiler.

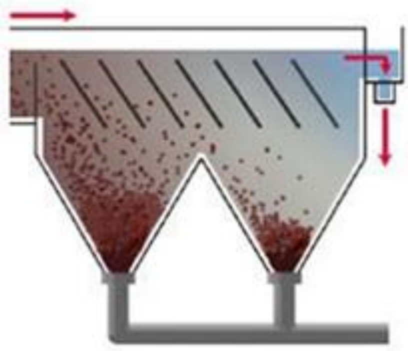

Figure 6. An illustration of a sedimentation tank

Cyclone: In *Figure 7*, the process within a cyclone is illustrated. A cyclone uses cyclonic actions in order to separate particles from the flue gas. The flue gases are spun inside the cyclone and the centrifugal forces, created by the circular flows, separates the particles by throwing them towards the walls of the cyclone. The particles then fall down to the bottom of the cyclone where they can be removed. Furthermore there are two kinds of cyclones: single-cyclone separators and multi-cyclone separators. The single-cyclone separator consists of one main vortex while the multi-cyclone separator consists of several small-diameter cyclones with a vortex in each one. As the multi-cyclone separators are longer and smaller in diameter they are more effective in comparison with the single-cyclone separator, but do on the other hand produce a higher pressure drop.

Figure 7. An illustration of a cyclone

Electrostatic filter: In *Figure 8*, an illustration of an electrostatic filter is displayed. The electrostatic filter uses electrostatic charges to remove particles from the flue gas. On a basic electrostatic filter you typically find a row of thin vertical wires followed by several flat metal plates, which also are vertically positioned. The flue gas will then flow through the spaces between the wires, as well as passing through the metal plates horizontally. As a negative voltage is applied between the wires and the plates it ionizes the gas around the electrodes which in turn makes the negative ions to flow to the plates and charge the gas-flow particles. Due to negative electric fields, created by the power supply, the ionized particles then moves towards the ground plate and is collected at the collection plate as they start to form a layer. Thanks to the electrical pressure, the layer stays intact even if the flow of flue gas is high. The ground plates are on a regular time cycle cleaned from particles, by a hammer which mechanically knocks on the ground plates, making the particles fall off into a container.

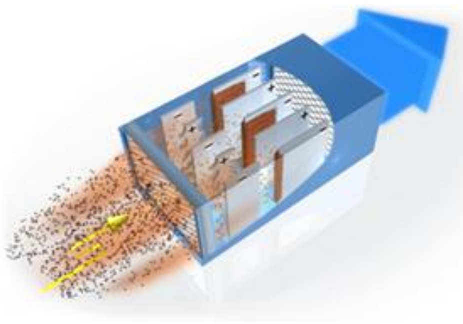

Figure 8. Illustration of an electrostatic filter

Fabric filter: One of the most common technologies for separation of particles is the usage of fabric filters, illustrated in *Figure 9*. A fabric filter consists of a baghouse that contains a large amount of oblong bags with a normal length of eight to ten meters. As the flue gas is pushed around and through the bags, the particles get caught on the outside. By inflating the bags using pneumatic compressed air, the bags are subject of a quick extension followed by a retardation. The reconversion between extension and retardation creates a quick whip in the fabric of the bags, shaking the particles off the bags down into a container below. As the bags are made out of fabric, a fabric filter is often preceded by a cyclone or similar which separate larger and flammable particles. If a flammable particle would reach the fabric filter, it would burn a hole through the filter and thereby decrease its separation efficiency.

Figure 9. Illustration of a fabric filter

Wet scrubber: To the right, *Figure 10* illustrates wet separation of particles. The most common wet separation is the use of wet scrubbers. As the hot flue gas is lead into the wet scrubber, several thrust nozzles spray the gas with fine distributed water. The particles are then captured within the droplets and follow the water droplet down to the bottom of the scrubber while the clean flue gas continues to move upwards. The liquid slurry with a combination of particles, dust and water in the bottom of the scrubber is then separated and can be cleaned by using ordinary water cleaning techniques, commonly seen in water cleaning plant.

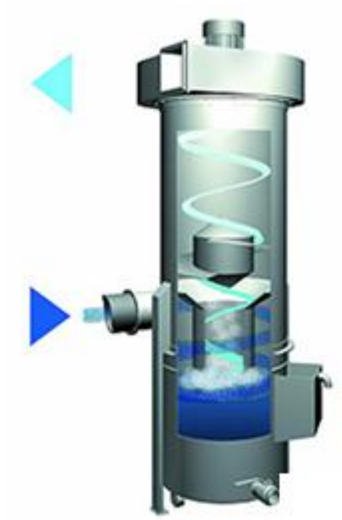

Figure 10. Illustration of a wet scrubber

Which of the above described technologies for mist elimination being suitable for a specific type of boiler depends on the effect of the boiler and thereby the flow/volume of flue gas as well as the type of fuel that is combusted. However, at the moment the lion share of the market and the general competition lies between electrostatic filter and fabric filters[2,3]. Electrostatic filters are, compared to fabric filters; a more mature product that has been in use and improved for over a century, while fabric filters first saw the daylight in the late 1970's. The improvements of the electrostatic filters has during the last decades at the most been on a small incremental level and has almost

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[2] Peter Wieslander Technology Manager - FF process Alstom, personal interview on the 20th of April 2010.
[3] Per Johansson Technology Manager - ESP Mechanical Alstom, personal interview on the 20th of April 2010.

reached a standstill, while the fabric filters has had a much steeper development curve during the same time period, especially concerning the cleaning process of the filters[4].

The difference between the two filtration techniques' development curves has been to an advantage for the fabric filters, which has started to gain market shares from the electrostatic filters. As can be seen in *Figure 11*, electrostatic filter holds about 60% of the total market share within flue gas cleaning at power plants. Fabric filter on the other hand holds about 40%[5], which in turn shows that the other techniques; sedimentation tanks, wet scrubbers and cyclones only constitute a fraction of the market. It is however noteworthy that for instance cyclones can be used in combination with either an electrostatic filter or a fabric filter, but is rarely seen by itself[4,6].

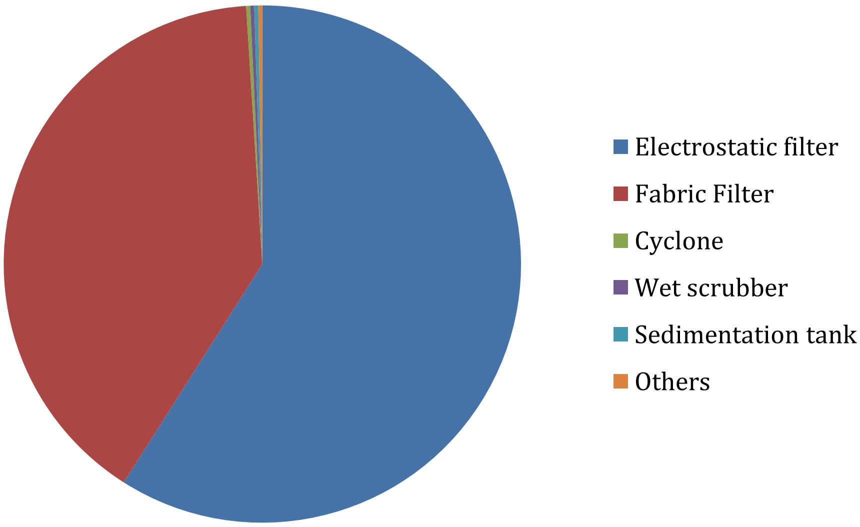

Figure 11. Different techniques market shares within particle separation

In a comparison between electrostatic filters and fabric filters, some general differences can be identified. An electrostatic filter is larger than a fabric filter considering both size and weight. The construction of an electrostatic filter consists of almost two and a half times more steel and requires almost double as much space compared to a corresponding fabric filter. The larger foot-print of electrostatic filters thereby makes them less attractive as retrofit-kits, since those by definition are assembled on a pre-existing boiler system where available land and space often is scarce. Fabric filters do on the other hand contribute with about 1500 Pa pressure decay, which is five times as high as for electrostatic filters.[4]

From a financial perspective, the two techniques are both advantageous depending on the criteria they are measured by. The electrostatic filter is for instance about 40% more

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[4] Peter Wieslander Technology Manager - FF process Alstom, personal interview on the 20th of April 2010.
[5] Per Johansson Technology Manager - ESP Mechanical Alstom, personal interview on the 20th of April 2010.
[6] Mikael Larsson Manager - Technology Managers Alstom, personal interview on the 20th of April 2010.

expensive in terms of investment costs, but consumes 35% less energy and requires 75% less maintenance[7]. The fabric filters will therefore initially be cheaper to buy, but becomes more expensive than the electrostatic filter in the long run. However, according to Wieslander[8] the investment cost is still often a heavily weighted criterion for the customers, which in turn works in favour for the electrostatic filters.

In terms of particle separation, both techniques withhold very high separation efficiency. Although, once again the combustion fuel is of interest, especially concerning the usage of electrostatic filters. The electrostatic filter efficiency depends on the possibility to electrically charge the particles in order for them to get attracted by, and stuck on the ground plates. The possibility to electrically charge the particles depends on the electrostatic resistance of the material, and thereby the composition of the material.[7] The particles from coal have very different electrostatic resistivity depending on origin of the coal. Coal from Poland or the US have low electrostatic resistivity and works therefore effective in combination with electrostatic filters, while coal from for instance Australia has high resistivity and therefore makes electrostatic filters a less proper separation technique for that sort of coal[7]. The problem often gets even more complex as power plants usually buys and combusts coal from different mines in different countries depending on the price on the spot market for coal. In order to control the level of particle separation, the tolerated maximal amounts of different kinds of coal are often regulated in some form of a contract when using electrostatic filters[7]. Concerning bio-fuels which are a common fuel in Scandinavia and especially Sweden, there are no restrictions for either electrostatic filters or fabric filters in terms of particle resistivity. (Parker, 2003)

As earlier mentioned, the separation efficiency of the two technologies is high. Both electrostatic filters and fabric filters separates particles down to a size of 1 μm with a collection efficiency of 99.8%. Below 1 μm there is however a slight advantage for the fabric filters which can retain a constant collection efficiency of 99.5% down to 0.2 μm. The collection efficiency for electrostatic filters in the same size span is about 98% or lower.[8]

3.3 Environmental legislations

The legislations for plants burning combustion fuels are country specific. Each country set their own legislations regarding acceptable levels of emissions. Most countries, including Sweden, has different types of regulations such as laws, general advices or terms for controlling the emissions or the level of harmful particles in them. Since the 1th of January 1999, Sweden has a coordinated environmental legislation called *Miljöbalken*

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[7] Per Johansson Technology Manager - ESP Mechanical Alstom, personal interview on the 20th of April 2010.

[8] Peter Wieslander Technology Manager - FF process Alstom, personal interview on the 20th of April 2010.

(SFS 1998:808) which deals with this sort of regulations within the Swedish law system. (ÅF Energi & Miljöfakta, 2009)

Although, since Sweden is a member of the European Union, and each member state must adapt to the EU-constitutions as they are directly applied, legislations which are dealt with in the EU-constitutions are valid above the national legislation. Many of the EU-constitution's legislations were however written into the Swedish legislations as it was constructed, but it is far from finished and has been an ongoing process as legislations change with time. (ÅF Energi & Miljöfakta, 2009)

One important rule regarding the Swedish Miljöbalken concerns the reversed burden of evidence. The reversed burden of evidence means that it is the legal entity behind an organization that needs to prove that its operations meet the legislations instead of the other way around (ÅF Energi & Miljöfakta, 2009). In the case of Swedish power plants this means that the power plants themselves must measure and control their emissions.

In Sweden; the government, the environmental courts, the county administrative board and the commune tests matters concerning Miljöbalken depending on the size of the power plant. Power plants with an effect of over 200 MW are tested in the environmental courts, plants with an effect between 10-200 MW are tested in county administrative board and smaller plants with an effect under 10 MW does only need to be tested in the local commune. If the plant has an effect less than 0.5 MW the only requirement is a building permission. (ÅF Energi & Miljöfakta, 2009)

Regarding emission levels in terms of dust and particles, each permission trial of a power plant are individually decided in the forums described above. The decisions are however generally heavily influenced by the general advices regarding solid combusted fuel facilities brought together by the Swedish Environmental Protection Agency (EPA). The general advices regarding emission levels for dust and particles provided by the Swedish EPA can be found in table 1 and 2 below. (ÅF Energi & Miljöfakta, 2009)

Table 1. Limit values of emissions regarding dust and particles for existing plants

Type of fuel and size of the plant [MW]	Limit value for emissions [mg/Nm^3]
Solid fuels ≥ 500 MW	50
Solid fuels < 500 MW	100
Liquid fuels ≥ 50 MW	50
Blast furnance gases ≥ 50 MW	10
Other gases from the steel industry ≥ 50 MW	50
Gaseous fuels in general ≥ 50 MW	5

Source: Swedish EPA, regulation NFS 2002:26

Table 2. Limit values of emissions regarding dust and particles for new plants

Type of fuel and size of the plant [MW]	Limit value for emissions [mg/Nm^3]
Solid and liquid fuels 50-100 MW	50
Solid and liquid fuels > 100 MW	30
Blast furnance gases ≥ 50 MW	10
Other gases from the steel industry ≥ 50 MW	30
Gaseous fuels in general ≥ 50 MW	5

Source: Swedish EPA, regulation NFS 2002:26

3.4 The different combustion fuels

There are numerous of different types of combustion fuels for boilers at thermal power stations, energy plants or a combination of them both. The most commonly used fuels can be divided into two clusters: fossil fuels and bio-fuels.

Fossil fuels are fuels that are developed by nature as a result of the anaerobic decomposition of buried dead organisms, such as plants and animals. Following fuels are gathered here under the umbrella term fossil fuels: Coal (hard coal and brown coal), Oil, Petroleum, Methane, Peat and Hydro carbon.

Bio-fuels on the other hand are a wide range of fuels which are derived out of biomass. The bio-fuels could either be in solid phase, liquid phase or gas phase and the following bio-fuels are suitable for combustion burning in a boiler: pellets, chips, ethanol, bark and firewood. From an environmental point of view, the bio-fuels are often referred to as more environmentally friendly as the biomass absorbs the same amount of carbon dioxide during its life cycle as it releases during the combustion. In other words, it becomes a zero-sum game were the amount of carbon dioxide in the atmosphere remains unchanged. Another positive aspect regarding the bio-fuels is the possibility to replant the same amount of biomass that is consumed. A possibility that is not available for fossil fuels, which thereby becomes a scarce resource. Furthermore, as bio-fuels naturally consist of a relatively high percentage of moist the flue gas will have a high level of moisture compared to flue gas from fossil fuels.[9]

As many countries' governments during the last decades have started to tighten the regulations for waste deposition, a third type of fuel has arisen. Waste incineration is an alternative to waste deposition which combust about 80% of the waste, leaving only 15-20% of the original waste into ashes and other rest products that can be used as filling material in for example road construction. Waste can be considered as a combination of bio-fuels and fossil fuels as it contains both fuel types depending of the substances within the waste. However, even if the waste contains fossil fuels such as plastics or oil,

[9] Martin Östlind Sales manager - Nordic Countries Svensk Rökgasenergi AB, personal interview on the 10th of Feb 2010.

the lion's share of the waste is made up of bio-fuel, which in turn contributes to flue gases with a high level of moisture.[10]

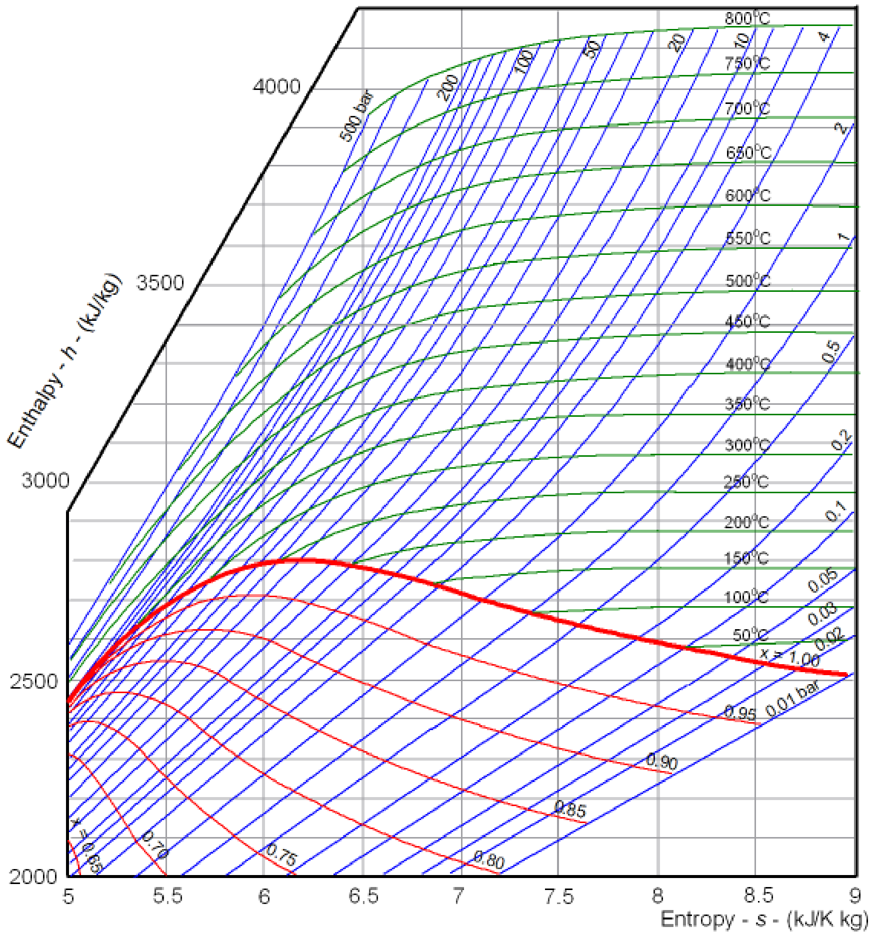

Figure 12. The Mollier diagram for water-steam

The moisture level of a flue gas is an important criterion when studying flue gases from a heat recovery perspective. This due to the fact that gas of a curtain temperature with a high percentage of moisture contains more energy than gas with the same temperature, but with less moisture. This relation is further illustrated in *Figure 12* were for instance a steam with a temperature of 50° C with a 0,5 moisture level is higher up on the red line compared to the a steam with a 0,1 moisture level. Furthermore is a gas that withholds a high percentage of moisture referred to as saturated, while gas with low percentage of moisture is referred to as unsaturated.

From a practical perspective, large amounts of energy are captured as the steam is cooled down to the dew point and the moisture within the steam is transformed back into water. The large amount of energy once consumed in order to sublimate the water into steam will then be returned as the medium condensate back into its original state. Therefore is a flue gas with high moisture level more attractive from an energy

[10] Ulf Hägg Manager - Process Design Götaverken Miljö AB, personal interview on the 23th of Feb 2010.

perspective compared to a gas with low moisture level, since more energy can be extracted from the one with high level, when condensed.[11,12,13]

Due to the differences in amount of moisture within the different types of fuels, different techniques are suitable in order to recover heat. For the fuels which contain a high percentage of moisture, such as bio-fuels, condensation has been the most common and well spread heat recovery technique[11]. On the other hand, for fuels which contain a low percentage of moisture, the transformation to the water phase using the condensation techniques with thrust nozzles requires an equivalent amount of added energy as the one it extracts, and therefore becomes a zero-sum game.[14] As the condensation technique is central in terms of heat exchange of flue gases, it will be further explained and developed in the following sub-chapter.

3.5 Heat recovery of hot flue gases

If the hot flue gas has a high moisture level, flue gas condensation can significantly increase the energy efficiency at a heat plant or a combined power and heat plant. The maximal recoverable heat is determined by the ambient conditions, both within the system as well as the combustion fuel. The heat system's efficiency can increase with up to 20% due to the earnings of latent energy in the steam. (Neuenschwander, Good, & Nussbaumer, 1998)

There are however not only positive aspects from recovering heat from flue gases and thereby lower the temperature of the gas. Almost all materials accept some few wood fuels contain more or less amounts of sulfur. When material containing sulfur are combusted, steam containing sulfur acid originates at a temperature between 200-560°C. As the temperature of the flue gas decreases, the sulfur acid steam will eventually transform into sulfur acid when the sulfur acid steam's dew point is reached. The dew point for when sulfur acid steam transforms into sulfur acid is between 70-170°C, depending on the concentration of sulfur. Condensation of sulfur acid steam is the main cause of corrosion attacks on surfaces that are in contact with flue gases. Corrosion as an effect of sulfur acid does often appear in form of an evenly spread out material rarefaction or a deepening in the material. However, if the concentration of sulfur can be below 1%, the problems of corrosion decrease substantially. Another method for decreasing the corrosion attack is to add MgO, $MgCO_3$ or dolomite, but the easiest and cheapest way to avoid corrosion is to keep the temperature above the sulfur acid's dew point. (Jernkontoret, 2007)

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[11] Martin Östlind Sales manager - Nordic Countries Svensk Rökgasenergi AB, personal interview on the 10th of Feb 2010.
[12] Tomas Börjesson CEO Radscan, personal interview on the 17th of Feb 2010.
[13] Ulf Hägg Manager - Process Design Götaverken Miljö AB, personal interview on the 23th of Feb 2010.
[14] Rolf Christensen Business Development Manager Alfa Laval, personal interview on the 18th of Mars 2010.

Due to the problems of sulfur acid, discussed above, the most appropriate flue gases to heat exchange are those made out of wood fuels, which to some extent explain why heat recovery of flue gas from other types of fuel such as coal is as undeveloped as it is. Therefore, if the flue gas from other materials than wood fuels shall be heat exchanged, the problem of sulfur acid and corrosion needs to be solved.

If wood on the other hand is used as combustion fuel, there is no problem with sulphur and the gas is suitable to condensate due to the fact that the flue gas typically contains around 10-20% of steam. Fresh cut wood does furthermore naturally contain more moisture compared with wood that has been stored, and thereby to some extent has dried. However, even if the type of fuel affect the amount of steam in the flue gases it is not the only important factor. Below follows 12 factors which all impact the efficiency of the condensation of the flue gas. Six of the factors depend on the plant's design and operations while the other six factors depend on the plant's technique and heating system. (Neuenschwander, Good, & Nussbaumer, 1998)

Design and operational dependent factors:

- Fuel composition
- Fuel humidity
- Fuel temperature
- Ambient air temperature
- Ambient air humidity
- Ambient pressure and altitude

Technique and heating system depending factors:

- Excess air ratio
- Burn out quality
- Boiler losses, boiler room losses
- Flue gas temperature
- Temperature of the condensed water
- Return temperature of the district heating system

In a typical condenser, the condensing function is based upon spherical water droplets which are sprayed at the gas, using thrust nozzles. The surface area of the spherical water droplets constitutes a very large mechanical heat exchanger surface which is used to lower the temperature of the gas, toward the dew point. As the flue gas is heavily cooled, it cannot withhold the same amount of water in the gas phase and the water vapour starts to condensate. The heat captured in the gas is transferred into the fluid which in turn is heat exchanged against the district heating system. (Svensk Rökgasenergi, 2010)

As the condensation of the steam begins, the precipitate flows down the inner sides of the condenser into a catchment vessel. Since the steam has transformed into water, the amount of precipitate in the catchment vessel is larger than the amount of sprayed water. Furthermore, since the flue gas is warmer than the sprayed water, the water temperature will increase simultaneously as the gas temperature decreases. The precipitate will therefore withhold a higher temperature compared to the input water. It is this difference in temperature that is valuable and possible to heat exchange (Svensk Rökgasenergi, 2010). In order to not consume enormous amounts of fresh water, the precipitate is connected back to the thrust nozzles in a loop. The extra amount of precipitate which is added due to the condensation is tapped of via a water cleaning system to the sewer system. In *Figure 13* below, an example is illustrated with a 100 MW boiler that is using a condenser. Given a fixed flue gas temperature, 55% moisture content in the fuel and a precipitate temperature of 50°C, the condenser would add 32 MW extra to the plants energy production, which corresponds to a 32% increase.

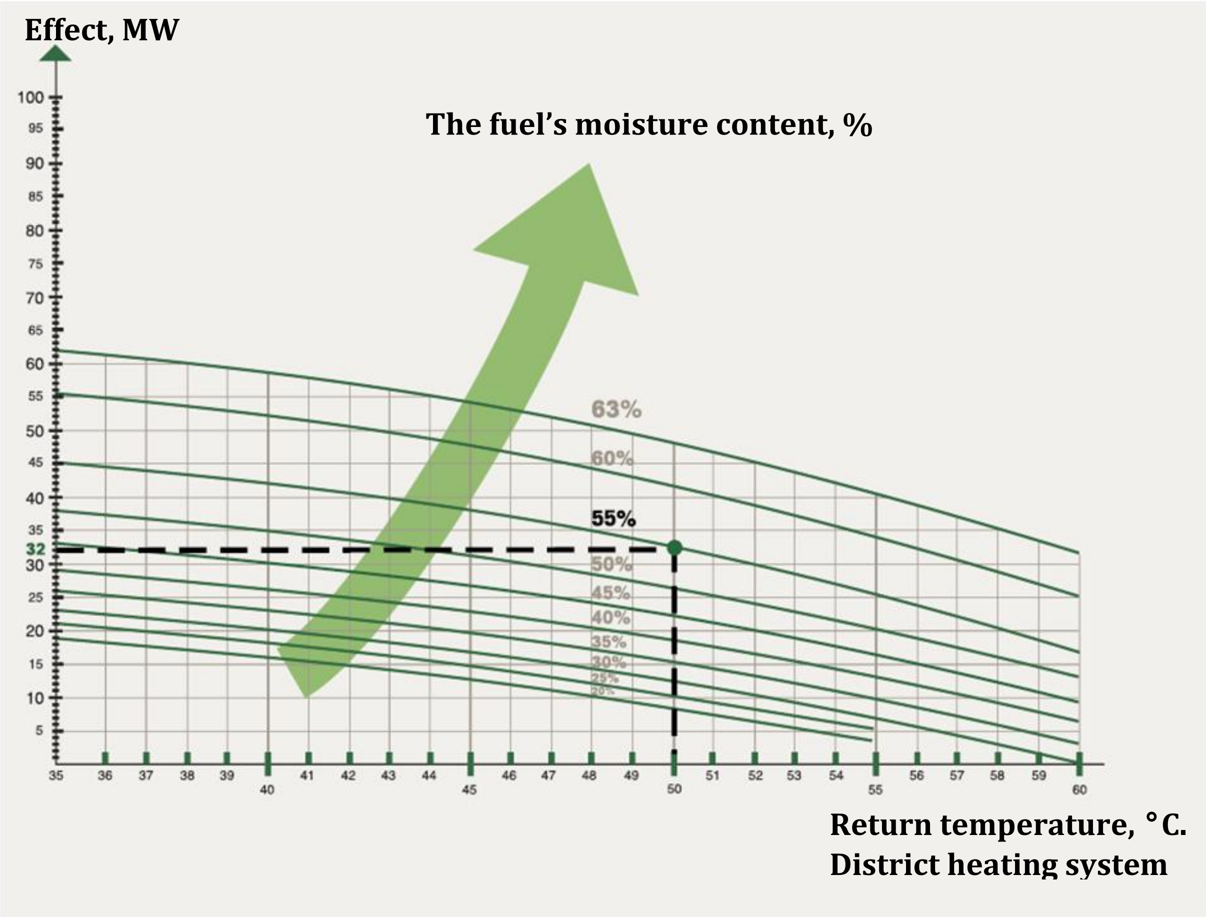

***Figure 13. The relationship between the moisture level of the fuel and the return temperature of the district heating system and its influence on the added effect* (Svensk Rökgasenergi, 2010)**

Although, heat exchanging in itself does not add any value if there are no feasible receiver that can take charge of the increased temperature provided. At the market today, the lion share of such receivers consists of the local district heating system. Therefore, in order to add value through condensing flue gas, the return temperature of the district heating system needs to be lower than the feasible temperature of the precipitate[15,16,17]. The requirement of an existing district heating system narrows down the potential markets for where condensation can be applicable. Generally speaking, it is possible to claim that condensation as technique is suitable for countries with a cold climate[15]. Hence, as shown in *Figure 14* a line could be drawn approximately in the middle of Europe, illustrating where the conditions for the condensation technique are present from a climate perspective.

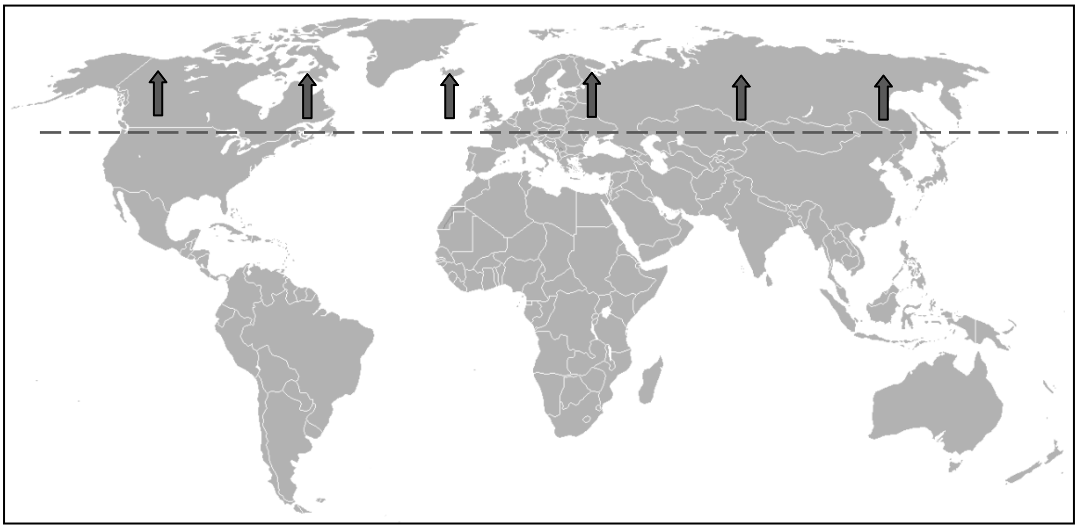

Figure 14. The parts of the world with high enough moisture level for condensation

The climate is however not the only important condition. As earlier mentioned, the return temperature of the district heating system is an essential boundary condition that further narrows down the market for condensation. In for instance Russia, that has the largest district heating system in the world in the cities of Moscow and St Petersburg, the return temperature is extremely high due to age of the district heating system[18]. The obsolete district heating system therefore makes it impossible to gain any value from condensation in Russia. When the return temperature of the district heating system is added into the equation, only a handful of countries could still capture the benefits of condensation.

[15] Lennart Granstrand Founder and Development Manager Svensk Rökgasenergi AB, personal interview on the 10th of Feb 2010.
[16] Tomas Börjesson CEO Radscan, personal interview on the 17th of Feb 2010.
[17] Ulf Hägg Manager - Process Design Götaverken Miljö AB, personal interview on the 23th of Feb 2010.
[18] Martin Östlind Sales manager - Nordic Countries Svensk Rökgasenergi AB, personal interview on the 10th of Feb 2010

3.6 Trends within electricity generation

Due to several political decisions and regulations during the last couple of decades, bio-fuels have captured large market shares on the electricity generation market in Sweden (Sjöbohm, 2007). The bio-fuel trend is however Sweden specific, which in turn makes it a very small niche market compared to the rest of the worlds electricity market. An overview of the European electricity production per type of fuel is provided in *Figure 15* below.

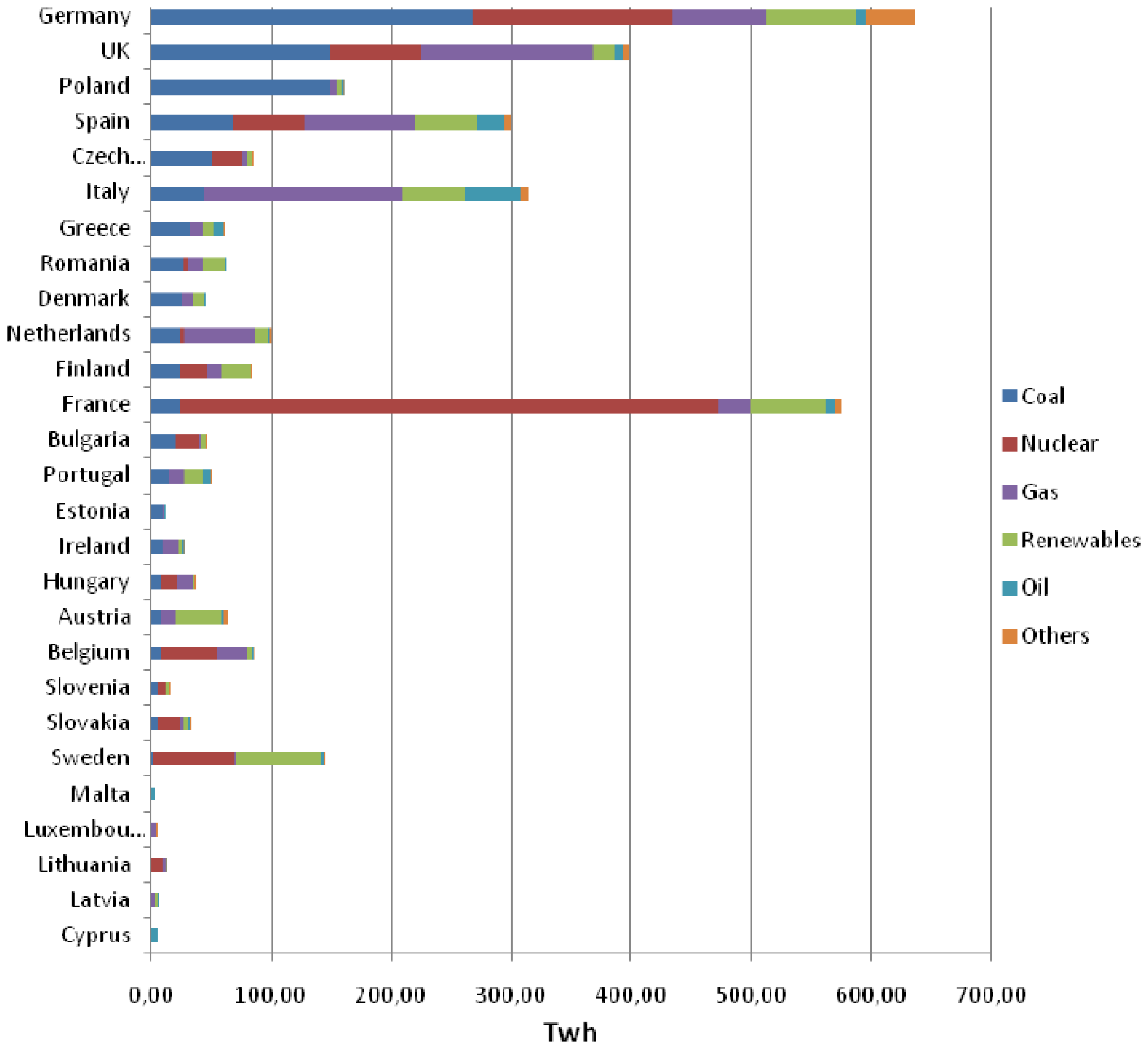

Figure 15. The European countries electricity production per type of fuel **(European Comission, 2010)**

In contradiction to the Swedish trend, European electricity producers are increasing the use of fossil fuels, especially coal and gas. Outside of Sweden, the electricity produced from coal constitutes about 30% of the total amount of electricity, compared to about 0.5% in Sweden (European Comission, 2009). Furthermore, by looking at statistics for planned electricity generation projects during the up-coming 15 years (see *Figure 16* below) a lot of new coal, gas and wind power plants will be built within a time period of five years followed by investments in nuclear power. The investments in power plants combusting bio-fuels are however mediocre at best. (European Comission, 2009)

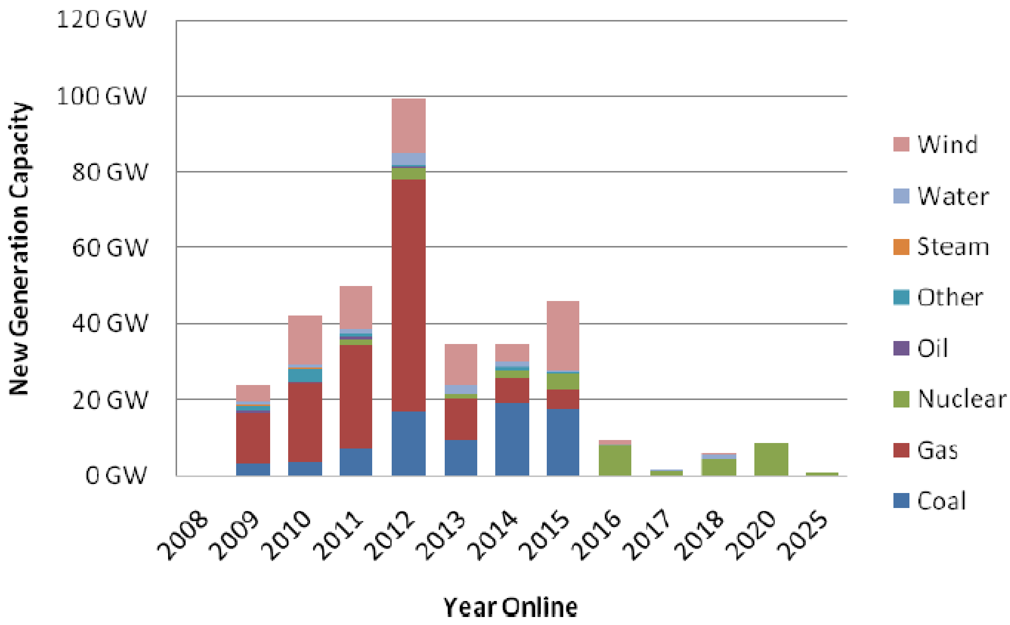

Figure 16. Planned electricity generation capacity until 2025 **(European Comission, 2010)**

The usage of coal combustion for electricity generations has had a steady increasing trend. In 2007, the world's coal production increased with 5.6%, which was somewhat lower compared to the increase of 7.6% in 2006, but higher than the 10 year average increase of 3.4%. Although, the use of coal in electricity generation varies widely within Europe and the European countries. In Poland, the coal constitute over 90% of the total electricity generation while it in France only constitute 4%. (European Comission, 2009)

3.7 Estimation of the market size

The price for electricity during the last couple of years has stayed about 10 Euros per 100 kWh for the industry and about 17 Euros per 100 kWh for households within the EU27. In 2007, the EU27 had a total gross electricity generation of 3,362 TWh, creating a 336-571 billion Euro market. As coal generated electricity constituted 29.4% of the total generated electricity during 2007, the coal generated electricity alone provided a 99-168 billion Euro market. Bio-fuels on the other hand only made up 3% of the total generated electricity within the EU27, generating a 10-17 billion Euro market. (European Comission, 2010)

By studying the distribution of boilers on the market based on their size, it is possible to argue that there is a positive misdistribution where the amount of small boilers heavily outnumbers the large ones. In Sweden for instance, there are over 1,000 boilers stretching from below 1 MW to above 560 MW. However, over 85% of the Swedish population of boilers has an effect of 30 MW or below, see *Figure 17*. (Svensk Fjärrvärme, 2010)

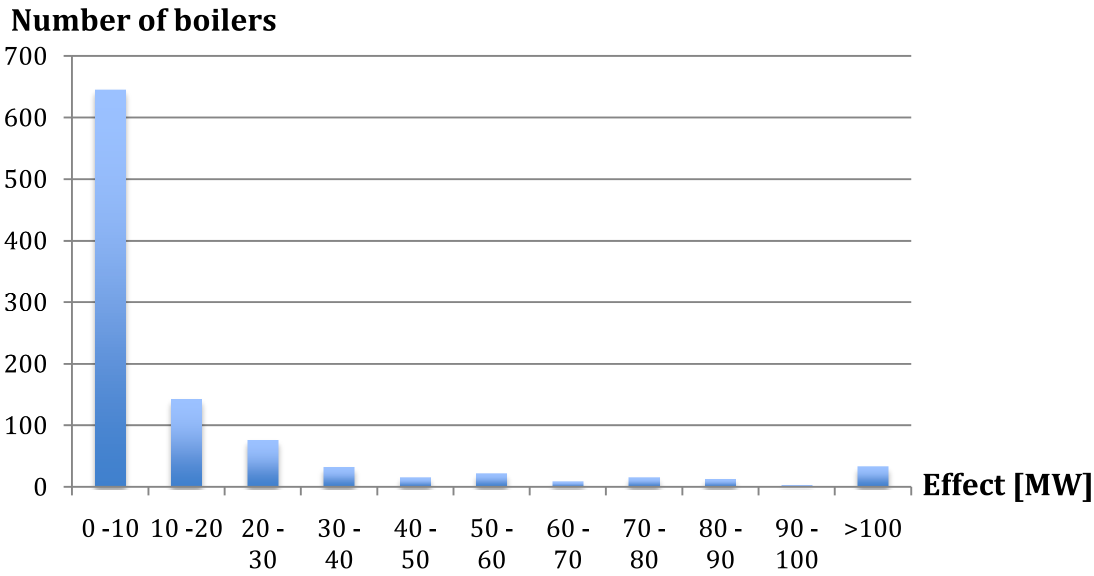

Figure 17. Distribution of the Swedish boiler population **(Svensk Fjärrvärme, 2010)**

Even though the Swedish energy market is somewhat misleading due to the high percentage of bio-fuel boilers which in general are smaller compared to for instance coal-fired boilers, the distribution can be generalized to the world market.[19,20,21,22]

If the distribution regarding the effect of the Swedish nation's boilers can be generalized, it is possible to make an estimation of the amount of boilers in the range of 0-30 MW within the European Union. According to statistics from Svensk Fjärrvärme (2010), there are 1006 boilers in Sweden which jointly, according to statistics from the European Commission, see appendix III, had a production capacity of 34,294 MW in 2007. In other words, the mean value for each boiler's production capacity was about 34 MW. As the EU27 countries had a jointly electricity production capacity of 777,192 MW in 2007, it would require over 22,900 boilers to achieve that amount of capacity given that the capacity mean value for each boiler stays the same. Furthermore, given that 85% of the boilers are within the range of 0-30 MW, it is possible to argue that there are slightly above 19,450 boilers that have an effect less than 30 MW within the EU, creating a massive market for retrofit kits for flue gas treatment.

To further estimate the amount of boilers in the world in the range of 0-30 MW, similar calculations are performed. In this case, energy generation is used instead of production capacity, because production capacity is not provided in the statistics. The electricity generation in the world was 19,250 TWh in 2007 (Central Intelligence Agency, 2010), while the electricity generation was 3,362 TWh in EU27 (European Comission, 2010).

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[19] Peter Wieslander Technology Manager - FF process Alstom, personal interview on the 20th of April 2010.

[20] Martin Östlind Sales manager - Nordic Countries Svensk Rökgasenergi AB, personal interview on the 10th of Feb 2010.

[21] Tomas Börjesson CEO Radscan, personal interview on the 17th of Feb 2010.

[22] Ulf Hägg Manager - Process Design Götaverken Miljö AB, personal interview on the 23th of Feb 2010.

Given that EU27 has 22,900 boilers to achieve that electricity generation the mean generation of each boiler was 0.147 TWh in the EU27. By generalizing the mean generation in EU27 to the world, it would require 128,000 boilers to reach the world's electricity generation. Moreover, the world market would consist of approximately 110,000 boilers in the range of 0-30 MW, given that 85% of the boilers have an effect less than 30 MW.

3.7.1 Sensitivity analysis of the market estimation

As it is generally unsecure and hard to validate generalized data, such as the one used in order to generalize the population of Swedish boilers onto the European ones, a sensitivity analysis of the assumptions used has been performed.

The most fragile assumption in the market estimation is that the Swedish distribution of boilers, where 85% of the Swedish boiler population has an effect of 30 MW or less, is valid for the boilers within the EU27 countries as well. Therefore in order to make the market estimation less unsecure, a worst-case scenario and a best-case scenario has been created. In the worst-case scenario the distribution of 85% has been lowered with 15 percentage points to 70%, while the distribution has been increased with 5 percentage points to 90% in the best-case scenario. As the scenarios use different distributions, a span is created regarding the amounts of boilers within the EU27.

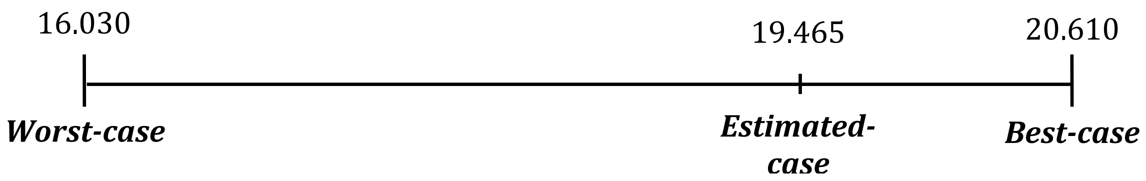

Figure 18. Sensitivity analysis of the market estimation for the EU27

As can be seen in *Figure 18*, even if the worst-case scenario is used there are still over 16,000 boilers only within the EU27. It is however noteworthy that the EU27 only is one of many big potential markets. The US market is for instance 30% bigger than the EU27 with an electricity production capacity of 1,010,171 MW (U.S. Energy Information Administration, 2010) compared to 777,192 MW in EU27. For more statistics on the U.S. electricity capacity, see appendix V. Other big potential markets are of course the BRIC-countries, which due to their large populations will have an increasing demand of electricity for many years to come. An example of this is China which has been building coal-fired power plants at a rate of roughly two per weeks during the last couple of years, and by doing so increasing their emissions with 11% annually (Inman, 2008).

The world estimated market with 110,000 boilers could in the same way be tested as the EU27 market. The same assumption regarding distribution of boilers was made here and is once again thought to be the most fragile assumption. By creating a worst case scenario with 70% and a best case scenario with 90% of boilers with an effect less than 30 MW, instead of the initial assumption of 85%, a sensitivity analysis is performed in

Figure 19. In the best case, 115,000 boilers would have a capacity less than 30 MW in the world and in the worst case the market would consist of 90,000 boilers with a capacity less than 30 MW.

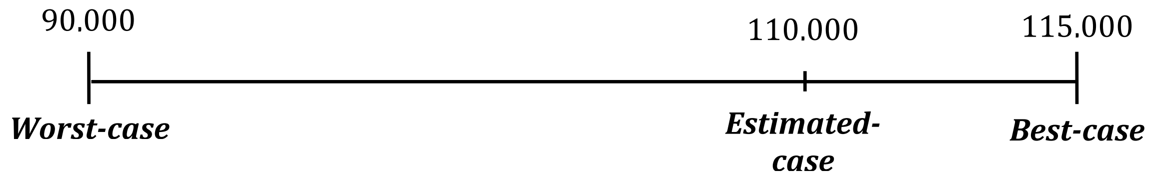

Figure 19. Sensitivity analysis of the market estimation for the world

As can be concluded by the sensitivity analysis, the market for flue gas treatment is vast even if low numbers are used.

3.8 The gas volume in relation to the boiler effect

The effect of the boiler is linear related to the consumption of fuel and thereby also the amount of flue gas produced. Every kilogram of fuel contains a specific amount of energy which is released as it is combusted. If twice as much is combusted of a specific fuel, it generates twice as much of flue gas. Even though the amount of flue gas can differ a little bit depending on fuel, most fuels can be generalized and argued to follow the plotted line in *Figure 20* below.[23]

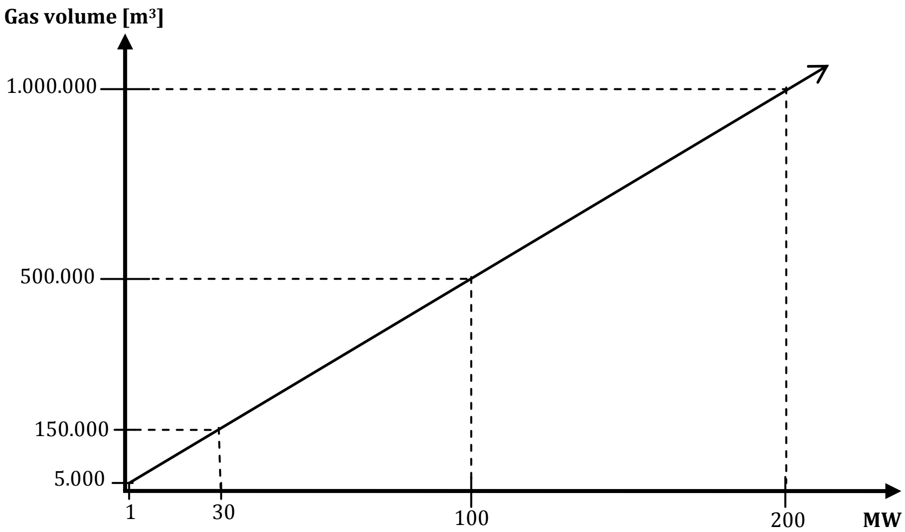

Figure 20. An illustration of the amount of flue gas in relation to the effect of the boiler

3.9 Summary of the empirical data

This initial chapter aimed at providing a basic overview of the boiler system and its surroundings. The chapter illustrated how the boiler population is misallocated and that there are considerably more small boilers compared to big ones. By studying statistics provided by Svensk Fjärrvärme, the chapter also provided evidence that over 85% of the

[23] Helena Roos Process Engineer Radscan, personal interview on the 17th of February 2010.

Swedish boiler population has an effect of less than 30 MW, a number which according to several leading actors on the market also is applicable for the rest of the world.

Moreover, the chapter provided an insight in the market of flue gas cleaning. The main conclusion from that part of the chapter is that electrostatic filters and fabric filters are the two major techniques within the area. The chapter did also provide some general data in terms of environmental legislations and established that within the European Union, the limit value for emissions in terms of particles is 50 mg/Nm^3 for new built plant and 100 mg/Nm^3 for existing plants. These values are however expected to tighten in the future.

In terms of heat recovery, the chapter established that it is mainly flue gases from biomass fuels that are worth to conduct heat recovery from. This since most of the latent energy in flue gases are bound as water vapor and can only be released through condensation. Accept from only having small amount of water vapor, flue gas from coal combustion contains sulfur which transforms into sulfur acid if the temperature is decreased below the sulfur acid steam’s dew point of 70-170°C.

In the end of the chapter, a market estimation was provided showing that there potentially are about 110,000 boilers within the span of 0-30 MWs around the world. Besides the market estimation, trends are provided showing the European Union’s future plans for electricity production. These trends show a clear increase of investments in coal, gas and wind power under the upcoming five years, which in turn illustrated that the market is growing.

4 THE MARKET FOR FLUE GAS TREATMENT

Chapter 4 focus on describing the existing market for flue gas treatment. The chapter furthermore aims to answering the competitive part of the first research question; "*What does the market characteristics look like in terms of competition, technical solutions and legislations?*", where the empirical chapter provided the answer to the technical solutions and legislations part of the question.

In order to answer the first research question both the market place as well as the key players within heat recovery and mist elimination are investigated and anylysed, which furthermore corresponds to the first cornerstone in *Figure 1*, earlier discussed in the background.

4.1 Literarture review

Chapter 4's literature review provides a theoretical framework as well as an analytical tool for estimating the market attractivness, developed by Micheal Porter.

4.1.1 Porter's five forces model

According to Michael Porter's five forces model the competitive intensity within an industry depends on five competitive forces. The accumulated power of the five forces determines the profit potential within an industry. A five forces analysis provides information upon which firms can base strategic decisions. The forces in Porter's theoretical framework are: *existing rivalry, threat of new entrants, supplier power, buyer power and threat from substitutes.* (Porter, 1980)

The threat from existing rivals is high within an industry if there are many actors that offer similar products or services. If the threat from existing rivals is high, this implies that competing firms will immediately mimic or in other ways respond to actions taken by another firm to improve its competitive position. Industries where such behavior is prevalent are often characterized by: high fixed costs, slow growth, equally powerful competitors, small differentiation and high shutdown costs. (Porter, 1980)

The threat of new entrants depends on the entry barriers surrounding an industry, making it more or less difficult for new firms to enter. For instance industries that require large investments in production equipment, such as car manufacturing, have higher entry barriers compared to, for instance a bakery. All in all, Porter identifies six forms of entry barriers, namely: scale economies, product differentiation, the need for capital, switching costs, disadvantage costs, government policies and access to distribution channels. On top of the six primary entry barriers, Porter furthermore claims that incumbents defense of market shares as well as the industry's growth rate is of high importance. (Porter, 1980)

The supplier power is the relative bargaining power enjoyed by the suppliers of a service or commodity within an industry. The suppliers have the possibility to practice pressure on the company in form of increases in price, quality and service levels et cetera. If the suppliers within an industry are powerful they will radically affect the profitability in a negative way. (Porter, 1980)

The buyer power is the potential for the buyers to put pressure on the suppliers of an industry by playing them against each other. The buyer power increases if, for instance, the buyers are concentrated, buying large volumes or if the products are standardized et cetera. If the buyers have large bargaining power, the industry will lose profitability. (Porter, 1980)

The threat from substitutes is the risk of becoming outcompeted by an alternative product or service provider which offers the same, similar or better function to the same or lower price. The substitution product which contributes to the largest threat is the one that shows the highest customer value or function in relation to price. (Porter, 1980)

Porter's five forces model has later been extended with a sixth force, namely power of complementary products. The producers of complementary products are those that supplies products which increase the value of the focal technology. The primary focus is then on how the value is shared between the products. It is argued that the producers with the stronger market position will increase its share of the total profits. (Grant, 2008)

4.2 A present analysis of the market for flue gas treatment

The market for heat recovery and particle separation is huge and involves hundreds of different actors within each specific field. The actors on the market vary in terms of both size and offerings; from small niche manufactures to large multinational cooperations that can offer a complete power plant.[24]

4.2.1 Key suppliers on the flue gas treatment market

From the vast amount of suppliers active on the flue gas treatment market some are selected for further analysis based on either their market share or their technology leadership. In order to create a more synoptical presentation of the relevant actors within the industry, the actors have been divided into four segments depending on what kind of products they offer in accordance with *Figure 21* below. The division of actors is valid for all actors besides Alstom and Siemens. Alstom and Siemens are unique in the sense that they have such a broad product portfolio that they can offer a complete power plant if a customer asks for it. In other words, Alstom and Siemens are present in all of four segments

[24] Mikael Larsson Manager - Technology Managers Alstom, personal interview on the 20th of April 2010.

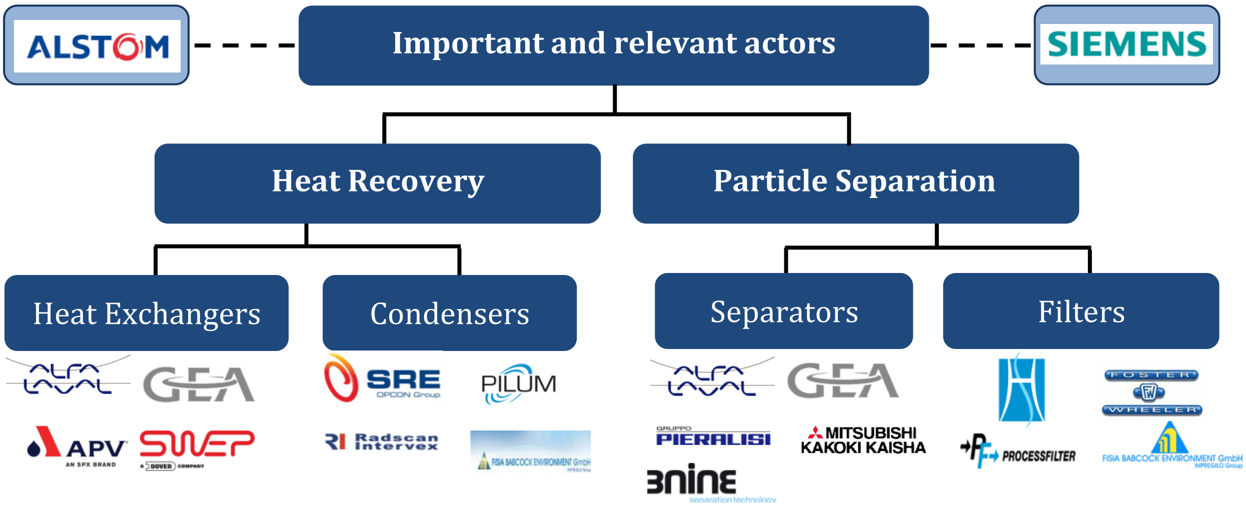

Figure 21. Division of actors based upon technology

Complete power and energy suppliers

As mentioned above, Alstom and Siemens are unique in the sense that they have the resources and capabilities to supply every part of a whole power plant. Both companies would therefore position themselves as a key supplier within each of the four technology areas; heat exchangers, condensers, separators and filters. In order to avoid repetition and redundancy, Alstom and Siemens will be presented prior the four technology areas.

ALSTOM Alstom is one of the world leading companies regarding infrastructure for transportation and energy, and is present in somewhat 70 countries around the world. Alstom's energy segment has a broad spectrum of products that includes turbines, water power systems, generators and flue gas cleaning plants. Currently, Alstom have supplied the major equipment in over 25% of the worldwide installed base within power generation. (Alstom, 2010)

Alstom has over 76,500 employees and a turnover of 196 billion SEK for 2009. The company was founded in 1928 and became registered on the Paris stock exchange market in 1998. Apart from several business collaborations, Alstom has governmental backing as the French state owns 21% of the company. The company furthermore has a strong innovative history and has provided the world's first nuclear steam turbine, the world's largest gas turbine as well as the fastest trains in the world. (Alstom, 2010)

SIEMENS Siemens offers their customers a complete energy solution from the production of oil and gas to power generation and the transmission and distribution of electrical energy. Only the energy sector alone within Siemens has over 85,000 employees and a turnover of 254 billion SEK for 2009. (Siemens, 2010)

Siemens strategy is to be a pioneer within new growing markets and is continually tapping new markets with innovative products and solutions. The innovative mindset has been a cornerstone within the company for over 160 years. Siemens was founded in Berlin, Germany by Werner von Siemens in 1847, but it was first in 1969 they entered the energy market through a collaboration with AEG. Siemens and AEG established Kraftwerk Union AG as a joint venture with a 50/50 split in terms of ownership. Although, in 1977 Kraftwerk Union AG became a wholly-owned subsidiary of Siemens and the company nowadays positions themselves as one of the leading companies within energy generation equipment. (Siemens, 2010)

Key suppliers within heat exchangers

Both plate heat exchangers as well as tube heat exchangers are both mature products on a mature market. As an effect of being a mature product, the amount of suppliers is massive. Therefore are only the key suppliers of heat exchangers listed below.

Alfa Laval is the leading manufacturer of plate heat exchangers and has been so for the last couple of decades. The company has broaden its product portfolio by also including a shell-and-tube heat exchangers but lack in terms of tube heat exchangers, which in turn has made them somewhat limited to plate-specific applications. (Alfa Laval, 2010)

Alfa Laval had a turnover of 26 billion SEK in 2009. Heat transfer products accounted for slightly below 60% percentages of that turnover. The company is world leading in terms plate heat exchangers and has an estimated market share of around 30%. Alfa Laval's plate heat exchangers are positioned in the premium segment, offering cutting edge technology and a heat transfer efficiency of 99.9%. The high quality and cutting edge technology has furthermore positioned Alfa Laval's products in the higher price segment as well. (Alfa Laval, 2010)

GEA is an internationally operating group where GEA Heat Exchangers constitute the largest segment with about a third of the total revenues. GEA Heat Exchangers offers a broad product portfolio with over 400 different heat exchangers within plate heat exchangers as well as both tube heat exchangers and shell-and-tube heat exchangers. GEA had a turnover of about 42 billion SEK in 2009 and constitute, together with Alfa Laval, one of the biggest actors of the world in terms of heat exchange solutions. (GEA, 2010)

APV was founded in 1910 and has long and well-established history in terms of heat exchangers. APV primarily offers plate heat exchangers, but has a tube-in-tube heat exchanger in its product portfolio. (APV, 2010)

In 2008 APV was acquired by SPX Corporation, a Fortune 500 multi-industry company with roots from the automotive industry. SPX's pre-existing business within heat transfer together with the acquisition of APV in 2008, has position SPX/APV as one of the biggest global heat exchanger suppliers in the world. The corporation had a turnover of 40 billion SEK, and the Flow Technology segment which their heat transfer technologies falls under provided 13 of the 40 billion SEK. (APV, 2010)

SWEP is an independent company within the Dover Corporation. The company was founded in 1983 and is a fast growing company within the heat transfer segment. In comparison with the companies mentioned above, SWEP is a smaller, fast-moving challenger with an yearly turnover of about 2 billion SEK. (SWEP, 2010)

Since the start-up in 1983, the company has expanded and is at the moment represented in over 50 countries, and has an established sales division in over 20 countries. SWEP further claims that they are world leading in terms of compact welded plate heat exchangers. (SWEP, 2010)

Key suppliers within separation

Just like heat exchangers; separators have a long history and a broad spectrum of applications areas. The development of separators is however steeper compared to the development of heat exchangers, which in turn makes it a less mature product. Even if separators have been around since late nineteenth-century, they are still evolving. They key suppliers of separators are listed below:

Separators are Alfa Laval's second core technology and their first separator was developed by Gustaf de Laval in 1877. Today Alfa Laval offers a broad spectrum of centrifugal separators and possess between 25-30% of the market. Just like in the case with their heat exchangers, Alfa Laval's separators are positioned in the higher price segment offering premium separators with premium quality. (Alfa Laval, 2010)

In terms of separation, Alfa Laval's separators has historically focused on separating different phases of liquids or separating particles from liquids, but has lately been extended to also include separation of particles from gases. The separator based sales accounts for about 22% of the total sales of Alfa Laval, which in turn makes separators a 5.7 billion SEK industry for the company. (Alfa Laval, 2010)

The GEA Group's separator products and solutions are provided by their mechanical equipment segment and are manufactured by GEA Westfalia Separators. Just as Alfa Laval, the company has a long history within separator technology and has over 115 years of experience within the knowledge area. Based on GEA's experience and size within the separation segment, they are considered as one of the leading companies within the field. (GEA, 2010)

MITSUBISHI KAKOKI KAISHA Established in 1935, Mitsubishi Kakoki Kaisha (MKK) is a Japanese company with over 75 years of experience within process technologies. The company has since the beginning had an extra focus on the chemical industry and chemical machinery. In 2009 MKK had a turnover of about 51.4 Billion SEK and delivers about 1000 disc separator units yearly. The company is primary present on the Asian market. (Mitsubishi Kakoki Kaisha, 2010)

GRUPPO PIERALISI The Pieralisi group is an Italian manufacturer established in 1888. The company originally supplied mechanical equipment for the olive oil industry, but broadened its product portfolio for separators during the 1970s to include several other industries such as chemical, food production et cetera. Pieralisi's separators are able to handle solid-liquid and solid-liquid-liquid separation, in other words both 2-phase and 3-phase separation. (Gruppo Pieralisi, 2010)

The Pieralisi group has a yearly turnover of about 1.8 billion SEK and around 650 employees. The company has an existing clientele of about 25.000 customers and has delivered above 40.000 separators. (Gruppo Pieralisi, 2010)

3nine separation technology 3nine is a new innovative Swedish company that develops solutions within air purification processes. The company had a turnover of 60 million SEK in 2008 with 16 employees and made a profit of 3 million SEK. Their technology is based on centrifugal separation, and makes it possible to achieve a high degree of purification in a very compact format. The company was founded in 2002 and is owned to the main part by Grimaldi Industri AB and SEB Venture Capital. The remaining part of the company is owned by the founders. (3nine, 2010)

The company has focused on three areas of application for its new technology: the manufacturing industry, heating plants, and the food processing industry. These are fields that combine large quantities of contamination with stringent demands for purification, including the purification of small particles, for example filtration of oil mist. (3nine, 2010)

Key suppliers within condensation

As condensation requires gases with high level of moisture which originate from combustion of fuels with high moisture level, most of the companies supplying condenser equipment are found either in Scandinavia or in the northern Europe. Furthermore, since the market for condensation is more geographically limited compared to the market for heat exchangers and separators, the companies are generally smaller. The key suppliers of condensers are listed below:

Fisia Babcock is a German based company that is a part of, and own by, the Italian IMPREGILO Group. The company's primary business consists of waste energy and gas cleaning in which it holds over 30 years of experience. Fisia Babcock has over 300 employees and has installed its products worldwide. (Fisia Babcock, 2010)

Fisia Babcock are using a wet scrubber technology which lower the temperature of for an example flue gas, making the water vapour condensate. The company offers full turnkey solutions for gas cleaning and condensation. (Fisia Babcock, 2010)

Pilum is in comparison with Fisia Babcock a smaller, national player on the Swedish market with a strong focus in the Nordic countries. The company is specialized within flue gas cleaning, water cleaning and heat recovery using condensation solutions. In 2008, Pilum employed 32 persons and generated a turnover of 120 million SEK. (Pilum, 2010)

Pilum uses either a wet scrubber technology or a plate heat exchanger in their condenser solutions. A Pilum condenser extract an additional 15-25% of the boilers total effect and by adding a humidifier it can extract up to 35%. (Pilum, 2010)

Radscan Intervex is a Swedish based company that offers turnkey solutions in terms of gas cleaning and heat recovery solutions using condensation technology. The company has a clear focus, targeting power plants with an effect of 50 MW and above. The company has 100 employees and a yearly turnover of about 165 million SEK. The company was founded in 1976, but started with flue gas condensation for the first time in 1999. Since 1999, Radscan Intervex has positioned itself as one of the leading providers of condensation equipment on the market. (Radscan Intervex, 2010)

Just like Pilum and Radscan Intervex AB, Svensk Rökgasenergi (SRE) offers flue gas cleaning and heat recovery solutions using condensation techniques. SRE does however focus on a completely different customer segment compare to the two prior companies. SRE is only working with small plants (<30 MW). SRE does furthermore offer a standardized and fixed price for their products and solution in comparison with for instance Radscan that always provides a tender for each customer. (Svensk Rökgasenergi, 2010)

SRE's condenser, Renergi GK, has always been the company's biggest business area together with the humidifier Renergi SBF. The company employees 25 persons and has for the last couple of years had a steady increase in sales in the Baltic countries and the rest of Europe. (Svensk Rökgasenergi, 2010)

Key suppliers within filtration

As mentioned earlier in the study, the big battle within filters is fought between electrostatic filters and fabric filters. The electrostatic filter is a more mature product with a long history, while the fabric filter is younger and still expanding, stealing market shares from the established electrostatic filters. The key suppliers of filter are listed below:

Fisia Babcock is a leading company in terms of electrostatic filters. The company offers electrostatic filters with a particle separation efficiency up to 99.95% that can handle flue gas volumes as big as four million m^3/hour. Fisia Babcock's electrostatic filters have historically been used for particle separation at power stations burning coal, lignite, heavy fuel oil or gas. Their product portfolio does furthermore also include wet electrostatic filters and fabric filters. The wet electrostatic filters have a particle separation efficiency of 99.97% which also removes aerosols and acid mist. For application areas with a temperature below 250°C, Fisia Babcock provides fabric filters with a capacity of 20 million m^3/hour and an efficiency of 99.95%. Due to its core knowledge within particle separation as well condensation, Fisia Babcok offers turnkey solutions for heat recovery and mist elimination. (Fisia Babcock, 2010)

Hamon Research-Cottrell (HRC) is an American based company and is one of the biggest filter manufacturers in the world. The company withhold over 40 years of experience in terms of fabric filter and over 100 years of experience in terms of electrostatic filters. The company does moreover offer a full range product portfolio regarding electrostatic precipitators, fabric filter baghouses, wet and dry SO2 and particulate scrubbers, urea to ammonia technology, and NOx control equipment. (Hamon, 2010)

In 2009 HRC had a turnover of 3.8 billion SEK which was only 5% less than 2008. HRC is a global company with presence and sales channels all over the world and has an installed base of over 5100 units, only within electrostatic filters. The company has furthermore invested a lot of money in order to enter the BRIC-market during the last couple of years, and in line with that strategy HCR bought 60% of China based DGE that is specialized in fabric filters. (Hamon, 2010)

Foster Wheeler is a global Switzerland based power equipment supplier with over 115 years of experience as construction contractor and within power solutions. The company is together with Hamon Research-Cottrell and Fasia Babcock one of the leading suppliers of mist elimination solutions in the world. Foster Wheeler has in similarity to HRC a broad product portfolio, financial strength and a truly global presence. (Foster Wheeler, 2010)

Processfilter is in comparison to Fasia Babcock and Foster Wheeler a smaller player on the filter market, but has during the last couple of years had an increasing growth and has become an important player on the Swedish market. Processfilter is a Swedish-based company with headquarter in Helsingborg, a subsidiary company in Weilerswist, Deutschland and presence on six of the seven world continents. The company offers a full span of filter and complementary products and has proved to be a solid innovative company within the area of particle separation. Moreover did Processfilter's owner and CEO, Niclas Blomquist receive the nomination "the entrepreneur of the year" in Sweden 2009. (Processfilter, 2010)

4.2.2 The disparity of buyers on the market

The buyers of flue gas treatment equipment differ in both size and complexity. At one side of the scale, small local boiler rooms can be found with an effect of 1 MW or similar. In the other side of the scale, the large multinational firms as Vattenfall, E-ON and Dong can be found that buys top of the line equipment for power plants with an effect of several hundred MW. As shown in the statistics in the empirical chapter, the boilers with a high effect, such as those owned by the big energy producers, are heavily outnumbered by the smaller boilers with less effect. A segmentation of the buyers can therefore be made; (1) the sales companies either focus on selling a few, large, state of the art, high tech solutions or (2) focus on selling bulk volumes of flue gas treatments solutions to boiler systems with less effect (0-30 MW).

One aspect which differs hugely between the two buyers segments are the procurement process. As large boiler system cost millions of SEK the procurement process is characterized by heavy competition, since many suppliers want to have a piece of the cake[25]. Hence, the margins are pressed down and the profit for the suppliers decreases. Moreover, are public procurements within the European Union with a value of over 10 million SEK forced to be publically displayed using the Official Journal of European Union. The OJEU is a public database where both new constructions and tenders are gathered jointly. The OJEU approximately receives about 160,000 invitations to tender annually and have over 40,000 registered organizations that use the service. As flue gas treatment for smaller boilers rarely exceed a price of 10 million SEK, the procurement process does not need to be publically displayed using the OJEU. (OJEU, 2010)

A final difference between the segments concerns the complexity of the system and its solution. The big boiler system is often one of a kind and thereby requires specialized treatment solutions. The small boiler systems are in opposite more commercialized, which opens up for a standardized treatment system. The difference in complexity is taken advantage of by for instance Svensk Rökgasenergi that has a standardized

[25] Tomas Börjesson CEO Radscan, personal interview on the 17th of Feb 2010.

condensation solution with a fixed price for small boiler system. (Svensk Rökgasenergi, 2010)

4.2.3 The attractiveness of the markets

A good tool to understand the specific business environment for heat recovery and mist elimination of flue gases is Porter's five forces model. By utilizing this model and adding a sixth force, all issues facing a new entrant can be examined. The model analyses the industries from six dimensions; *Existing rivalry, Threat of new entrants, Supplier Power, Buyer Power, Threat from substitutes and Complements* (Dorf & Byers, 2008).

Existing rivalry

The market for heat recovery of flue gases consist of a vast amount of competitors as mentioned earlier in the chapter. Some of the companies are turn key suppliers while others just deliver the heat recovery products for retrofit kits. This indicates that the size of the competitors may be very different, however many of the smaller competitors has recently been acquired by larger companies. Two examples are SRE that is owned by Opcon AB and Babcock & Wilcox Vølund A/S that recently acquired Götaverken Miljö AB. These acquisitions make the relative size of the competitors balanced, which in turn makes the competitors equally powerful and indicates high rivalry accordingly to Porter (1980).

The market for heat recovery of flue gases bloomed during the nineties and several companies entered the market. A more pessimistic view is held today and the market is declining, which indicates high competition accordingly to Porter (1980). Both Östlind[26] and Börjesson[27] state that the market for heat recovery of flue gas is mature and they are looking for other markets for their products. However, Hägg[28] points out that waste burning probably will increase in the future and thereby increase the growth rate of the market again.

Further evidence towards high rivalry are a small differentiation and that companies sometimes takes orders with a negative profit, just to reduce the fixed costs[27]. However, the exit barriers are deemed to be small, since production capacity often is bought from other companies.

The mist elimination market and in particular the market for fabric filters is growing accordingly to Wieslander[29]. The two most common techniques, fabric filters and electrostatic filters, are competing for the growing market. Wieslander[29] argues that fabric filters has strong advantages in comparison to electrostatic filters. However, in

[26] Martin Östlind Sales manager - Nordic Countries Svensk Rökgasenergi AB, personal interview on the 10th of Feb 2010.
[27] Tomas Börjesson CEO Radscan, personal interview on the 17th of Feb 2010.
[28] Ulf Hägg Manager - Process Design Götaverken Miljö AB, personal interview on the 23th of Feb 2010.
[29] Peter Wieslander Technology Manager - FF process Alstom, personal interview on the 20th of April 2010

some countries, for example in India, electrostatic filters constitute the whole market even though the advantages of fabric filters[30].

As in heat recovery of flue gases, the products offered are very similar and have comparable advantages despite patented solutions. That indicates a high treat from existing rivals accordingly to Porter (1980). Further evidence for high rivalry is that competition is primary based on price, since customers' willingness to substitute are high[31].

The competition within the industry is however lowered by a lock-in effect caused by the monitoring systems that the companies offer together with their products. As the personnel get accustomed with the monitoring system of one supplier the solution is locked-in, since a change of system would require new training of the personnel. The rivalry is also lowered by low fixed costs and low exit barriers. This since there are no investments needed in terms of production equipment as it is bought in from other companies or sub-suppliers.

The overall competition and rivalry within the industry of heat recovery is considered high, while it is judged to be medium to high within the industry for mist elimination.

Threat of new entrants

The competition in an industry will increase when new firms enter. Accordingly to Porter (1980), the entry of firms is in turn affected of barriers to entry, industry growth rate or incumbents' defense of market shares.

The industry growth rate has already been established as high for mist elimination, which possibly would attract new entrants. However, several entry barriers are found to be present in the mist elimination market. One of the most important is reference lists that constitute previous satisfied customers. Such lists are important since the projects undertaken often are of a significant cost and thereby also constitute a significant risk for the buyer. Another risk that is related to such projects concerns the emissions and the environmental legislations. If the project fails or if the mist elimination system is out of order, the whole plant may need to close down in order to not exceed the legislative demands.

Another entry barrier is the size of the projects, which requires financial strength of the entering firms. Financial strength is however not the only requirement, the industry is also knowledge and competence intensive. As the result of being a highly regulated

[30] Per Johansson Technology Manager - ESP Mechanical Alstom, personal interview on the 20th of April 2010.
[31] Peter Wieslander Technology Manager - FF process Alstom, personal interview on the 20th of April 2010.

industry, the knowledge requirements regarding cleaning techniques are crucial. For this purpose a network of people in related industries is a major advantage. Entry barriers are also created as switching cost to buyers occurs. One such example is the previously mentioned monitoring systems.

In contrast to the mist elimination industry, the heat recovery industry was regarded to be characterized by very low, if not negative, growth rate. Not only the growth rate but several entry barriers are of high importance. In similarity to the mist elimination industry, a reference list is valuable to attract customers as well as networks and know-how. The capital requirements are though not as demanding since most of the production is bought externally.

The overall threat of new entrants is deemed to be medium for the mist elimination industry due to high growth rate and high entry barriers. The contrasting growth rate of the heat recovery industry in combination with its high entry barriers indicates a low threat of new entrants.

Supplier Power

Within the mist elimination industry, most of the companies are not producing the offered products themselves. Instead the incumbents often act as project managers and distribute the production to different sub-suppliers[33]. According to Porter (1980), this gives the possibility for the suppliers to practice pressure on the incumbents. However, as argued earlier, the industry is both knowledge and competence intensive and the importance of reference projects as well as networks to related industries are high. In addition, the projects are often one of a kind which decreases the switching costs for the incumbents[32]. Furthermore there is a vast amount of certified suppliers to choose from which in turn provides the suppliers with low bargaining power.

The industry incumbents within the heat recovery industry do also act as project managers[33]. Components to the final solution are ordered from suppliers and then assembled into the final solution. The projects are most often a one of a kind that needs special calculations as well as knowledge of legislative demands. This specific industry is judged to not be important for the suppliers, because of its relatively low volumes compared to other industries. Furthermore, as in the case of the mist elimination industry, the number of certified suppliers is vast[33]. The overall bargaining power of the suppliers within the heat recovery industry could therefore be judged as low as well.

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[32] Peter Wieslander Technology Manager Alstom, interview on the 21[th] of April 2010

[33] Ulf Hägg Manager Götaverken Miljö, interview on the

Buyer Power

The buyers within the mist elimination and heat recovery industries are often very large energy producers with high profit margins and several plants in their portfolio. Examples of such producers are: Vattenfall, E-ON and Dong Energy.

As mentioned earlier, small incumbents have been acquired by large companies within the industry. This has in turn made the number of incumbents equivalent to the number of buyers, which according to Porter (1980) correspond to even bargaining power. However, in most cases the plants are managing the procurement process themselves and the energy producers are thereby not gaining scale advantages[34].

Furthermore, a lot of buyers are owned by governments within the European Union and are thereby obligated to publish all procurement over 10 million SEK in the OJEU (OJEU, 2010). Public buyers need to follow rules and reveal certain information about the projects with the aim to create a free and competitive market. Due to this process the bargaining power of the buyers is increased as the buyers can play the incumbent's tenders against each other.

However, the industry is important for the buyers of mist eliminator technology since the environmental legislative demands are not achieved without mist elimination solutions. The buyers also gain value if the solutions are developed in order to reduce their environmental impact, both regarding heat recovery and mist elimination. Although, the buyers still have high potential to put pressure on the incumbents when the OJEU is applicable and the buyer power could therefore be considered as high.

Threat from Substitutes

The industries for both heat recovery and mist elimination are mature. No substitute so far has been able to threaten the established solutions on either of the industries. It is furthermore the purpose of this thesis to investigate if any such opportunities exist whereby threats from substitutes are not developed further.

Threat from complimentary products

Compliments becomes important when they affect the demand for an industry's products or if the availability of value adding complimentary products are low (Grant, 2008).

One example of a complimentary product within the heat recovery industry of flue gases is the chimney. If the temperature of the water vapor within the flue gas is lowered below its dew point, it will start to condensate. If such a solution for heat recovery is used, all parts of the boiler system from that point and forward need to be made out of

[34] Joakim Mellström Technology Manager Fortum, personal interview on the 26th of March 2010.

corrosive free materials. One of the most common parts of the boiler system that needs to be replaced or modified is the chimney. In that way, corrosive-free chimney becomes a compliment product to heat recovery solutions of flue gases[35]. Hence the availability and cost of introducing a corrosive-free solution of the chimney needs to be considered. However, corrosive-free solutions are not unique for heat recovery industry of flue gases and Mellström[36] argues that the cost of a corrosive-free chimney in relation to the heat recovery solution would be negligible in the context.

Another complementary product for both the discussed industries is industrial fans. The solutions provided in terms of both mist elimination and heat recovery will create a pressure drop within the system. The pressure drop will in turn affect the chimney as it requires the flue gas to have a certain pressure in order for the gas to flow naturally. If the pressure would drop too much, an industrial fan would need to be installed. However, as industrial fans are both standardized and available, they do not cause any major threat against any of the industries.[35]

To summarize, no powerful complementary products for neither the mist elimination industry nor the heat recovery industry can be identified. The compliments mentioned above, fans and corrosive-free chimney are both standardized and thereby available on the market. Hence, the suppliers of complimentary products are believed to have a low bargaining power.

4.3 Summary of Chapter 4

Chapter 4 aimed at answering the market characteristics part of the first research question; "*What does the market characteristics look like in terms of competition, technical solutions and legislations?*".

In terms of actors on the market, the chapter pinpointed out that there are two major actors on the market, namely: Alstom and Siemens. Alstom and Siemens are both highly ranked among the fortune 500s and are large enough to offer a whole power plant with all the surrounding equipment. Moreover the chapter also provides a mapping of the key actors within each technology field, which illustrated that all markets had a variety of both large and small players.

The answer to the posed research question was also provided by an analysis of the industries' attractiveness using Porter's five forces model and a general description of the key actors on the markets. Based on the attractiveness analysis of the industries, it is possible to claim that both the industry for mist elimination heat recovery of flue gases from an overall perspective is attractive. However, as heat recovery of flue gases are only relevant in the northern parts of the world and where there exists a district heating

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[35] Göran Carlsson Owner and CEO Stål & Rörkonstruktioner AB, personal interview on the 4th of Feb 2010.
[36] Joakim Mellström Technology Manager Fortum, personal interview on the 26th of March 2010.

system with low return temperatures, the industry for heat recovery is considered a lot smaller than the industry for mist elimination.

Starting with the rivalry among existing firms, the industries are unattractive as it is characterized by heavy competition from both big and small players. However, the mist elimination industry is in contrast to the heat recovery industry still growing which makes it slightly more attractive in comparison. The threat of new entrants is however considered low in both industries since the markets contain several high entry barriers. Examples of such barriers are: required reference lists as well as financial strength. The bargaining power of the suppliers is considered low while the bargaining power of the buyers is considered high. Finally, the power of complementors is low as many of their products are standardized and thereby easy to purchase.

5 ALFA LAVAL'S RESOURCES AND CAPABILTIES

This chapter focuses on the core competences of Alfa Laval. The purpose of this chapter is to, based on the learning from the analysis of the present situation in chapter 4, provide a platform of relevant products from Alfa Laval's product portfolio which can be used in a potential system solution for flue gas cleaning and heat recovery. Chapter 5 does in other words study the intersection of cornerstone one and two, see *Figure 22*. By doing so, chapter 5 aims at answering the second research question; *What internal resources and capabilities does Alfa Laval possess that can be used or developed in a potential system solution for flue gas treatment?*

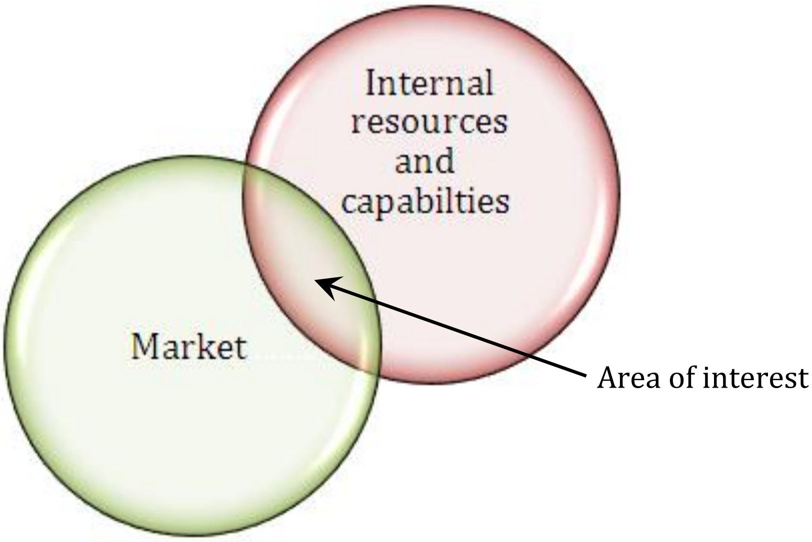

Figure 22. The focus of chapter 5

The chapter begins with a study of Alfa Laval's more abstract resources and capabilities in terms of brand, IPRs, management and corporate structure. The focus is then narrowed down, studying relevant products for flue gas treatment in their product portfolio. The study of Alfa Laval's products is divided into two categories, namely: heat exchangers and centrifugal separators. Each category addresses present, but also future products within each field.

5.1 Literature review

A company's ability to gain competitive advantages on a market is tightly connected to their internal resources and how these can be developed into capabilities. This mindset was first developed by Rumelt and Wernerfelt in 1984 and is called the resources based view. A further explanation of the resource based view follows below.

5.1.1 The Resource-based view

Firms can benefit from complementing the external view, which was examined in chapter 4, with an inside perspective of the firms' resources and capabilities since these set the limitations for the strategic actions the firm will be able to undertake.

Furthermore, in a world that is subject to constant and rapid change, basing long-term strategic decisions on firm's internal resources and capabilities, rather than more volatile market conditions, can provide a more sustainable competitive advantage and profitability. According to Grant (2008) resources relate to the inputs to production owned by the company, whereas capabilities describe the accumulation of learning the company possesses. Moreover Grant (2008) outlines that the organizational capabilities consists of three kinds of resources: tangible, intangible and human, see *Figure 23*.

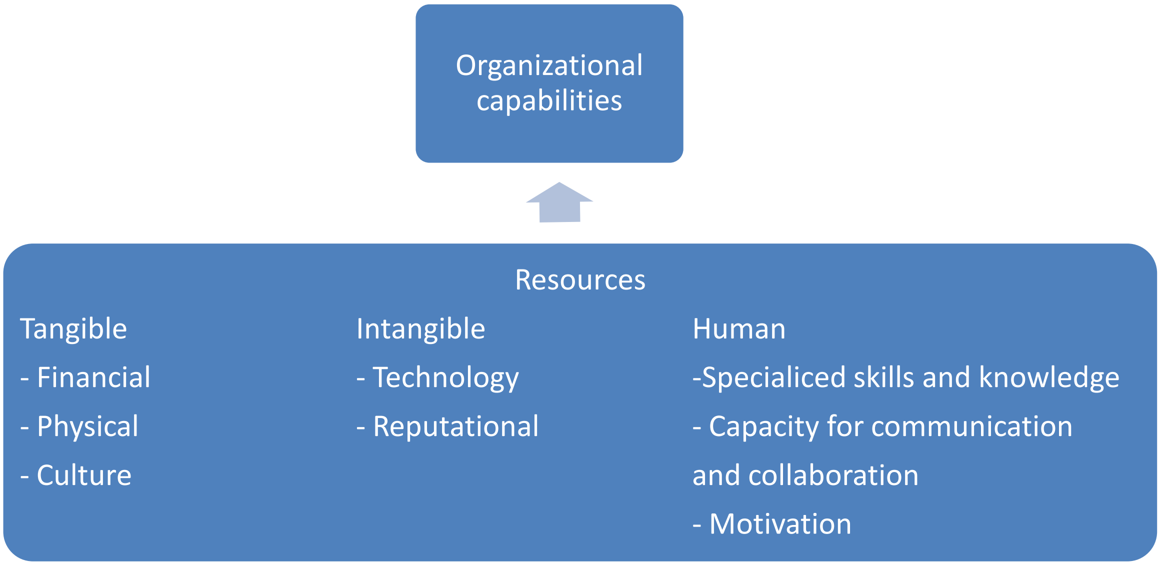

Figure 23. Organizational capabilities (adopted from Grant (2008)).

The resource-based view on strategy is based on the notion that superior profitability is not best achieved by doing the same things as other firms. Instead, firms should create a competitive advantage by implementing a strategy that exploits the firm's unique resources and capabilities. (Grant, 2008)

Applying the resource-based view on a firm means making an inventory of the firm's resources and capabilities, and thereafter evaluating them based on; (1) importance when creating a sustainable competitive advantage and (2) relative strength compared to competitors. (Grant, 2008)

The sustainability of a competitive advantage depends on the durability, transferability and replicability of the relevant resources and capabilities. Durability is related to the lifespan of the resources whereas transferability measures the resources' mobility between companies, in other words if it can be easily acquired by competitors. Low transferability indicates that the resource or capability has to be built in-house. Low replicability, associated with for instance organizational routines, indicates that the resource or capability is difficult to reproduce. (Grant, 2008)

Resources and capabilities scoring high on both importance and relative strength can be labelled as *key* resources and capabilities and will be exploited in order to attain a competitive advantage. Resources and capabilities that have scored high on strategic importance but low on relative strength also have implications for strategy since they, if improved, can be sources of competitive advantage. (Grant, 2008)

Capabilbities that are central to a firm's strategy and performance can also be labelled as *core* capabilities, or core competencies interchangeably. In order for a competence to qualify as core, it should be of utmost importance when generating customer value, open up for new markets and products and be either competitively unique or of substantially higher level compared to competitors. (Hammel & Heene, 1994)

As mentioned above, improving the relative strength of strategically important resources can provide a source for competitive advantage. However, Grant (2008) states in that when it comes to resources "investing in areas of weakness /…/ can be very expensive and, because of the complex complementaries between different resources, such investments may deliver limited returns." As for capabilities, he describes developing them as a "hazardous endeavour". (Grant, 2008, p. 142)

The problems associated with developing resources and capabilities partly stem from the fact that the relation between the two is somewhat unclear. However, it appears that it is the firm's ability to leverage its resources, rather than the volume of them, that determines its capabilities. (Grant, 2008)

One way for a firm to leverage its resources is *converging* them by concentrating on a small number of clearly defined goals and activities that customers perceive valuable. Resources can also be *conserved* which amounts to making the most of existing resources and capabilities by applying them to different products and markets (Grant, 2008)

5.2 An overview of Alfa Laval

To be able to evaluate a potential business opportunity within flue gas treatment, a better understanding of Alfa Laval's resources and capabilities is needed. Alfa Laval's strategy, organizational structure, present markets, R&D organization as well as products need to be taking into account in order to make a high quality evaluation of the resources and capabilities.

5.2.1 Alfa Laval's strategy

Alfa Laval has developed during more than one hundred years. From the invention of Sweden's first milk separator to become a global leading supplier of products and solutions for heat transfer, separation and fluid handling, Alfa Laval has constantly evolved. The transformation from a small national firm to a large global player has been accomplished through both internal growth and external acquisitions.

The strategy of Alfa Laval has changed during the years and has been strongly influenced by the ownership structure. One such example is Tetra Pak that acquired Alfa Laval in

1991 in order to offer a complete value chain from cow to consumer in terms of milk products. Alfa Laval was strongly influenced by Tetra Pak's competence and developed several new skills during Tetra Pak's ownership. These new skills later lead to the divestment from Tetra Pak to Industri Kapital in 2000. The intention of Industri Kaptial's acquisition of Alfa Laval was to publically list its shares on the stock market within a five-year period. In 2002, Alfa Laval returned to the Stockholm Stock Exchange with a repositioned brand and a new graphical identity. A new communicative strategy, which still shapes the company, was developed. The current communication strategy of Alfa Laval is to engage in optimizing the customer's processes using the theme of "Pure Performance". (Ehrenstråhle BBDO, 2010)

Today, Alfa Laval has an outspoken overall strategy to create profitable growth both organically and through acquisitions. The company's goal is to achieve an average annual growth rate of at least five percent; this aim is higher than the aim of Alfa Laval's competitors. Furthermore, Alfa Laval states that the company shall develop and expand the company's leading position in their well defined market segments. This can be achieved by systematically working with existing products, further developing the aftermarket sector and establishing new market concepts and key products. It can also be achieved through acquisitions and alliances that supplement and strengthen the company. (Alfa Laval, 2010)

The basis of the strategy for acquisitions and alliances is their business concept of optimizing the performance of their customers' processes, time and time again. This means that Alfa Laval shall undertake acquisitions or alliances: that strengthen the existing key products, that add new key products to the product portfolio or that complement the existing business in terms of geographical locations and new sales channels. (Alfa Laval Corporate AB, 2010)

Alfa Laval has proven that they can grow organically. One such example is the development and launch of ART, a new reactor technology for large scale production of pharmaceuticals. The new business area demand both new knowledge and networks within the pharmaceuticals industry in order to establish collaborations with the pharmaceutical companies. Such knowledge and networks was successfully obtained through close collaborations with several European universities as well as previously established contacts within the industry[37]. However, Norén[37] and Halac[38] state that Alfa Laval has failed to grasp business opportunities through organic growth at several occasions. Norén and Halac further state that one of the reasons is Alfa Laval's organizational structure.

[37] Tommy Norén Manager Technologies Alfa Laval, personal interview on the 7th of May 2010.
[38] Jaroslav Halac Manager - Mergers & Acquisitions Alfa Laval, personal interview on the 7th of May 2010.

One the other hand, external growth is one of Alfa Laval's strengths. During 2009 a total of six acquisitions were carried out, adding five percent in sales volume (Alfa Laval, 2010). Through these acquisitions Alfa Laval has proven to have the financial strengths and the management resources required to expand via acquisition. The target for 2010 is to spend four percent of the sales on acquisitions[39].

The company also has an external and internal environmental focus that aims to limit the environmental impact. Internally the company reduced their emissions from transportation by about 10%. Externally their offer includes products and services that help the customers save energy, produce freshwater, reduce emissions and minimize pollution. (Alfa Laval, 2010)

5.2.2 Alfa Laval's organizational structure

Alfa Laval employs almost 12,000 employees organizationally and is structured in three divisions; the operations division, the equipment division and the process technology division. The operation division is responsible for purchasing, production and supply of the company's products. The equipment division as well as the process technology division market and sell Alfa Laval's products in eleven customer segments. The organizational structure is developed in order to work closely with customers of various industries, and the sales personnel in each segment are specialized in their customers' processes. Besides the three divisions, Alfa Laval owns sales companies which are present in over half of the company's approximately 100 countries, see *Figure 24* below. (Alfa Laval, 2010)

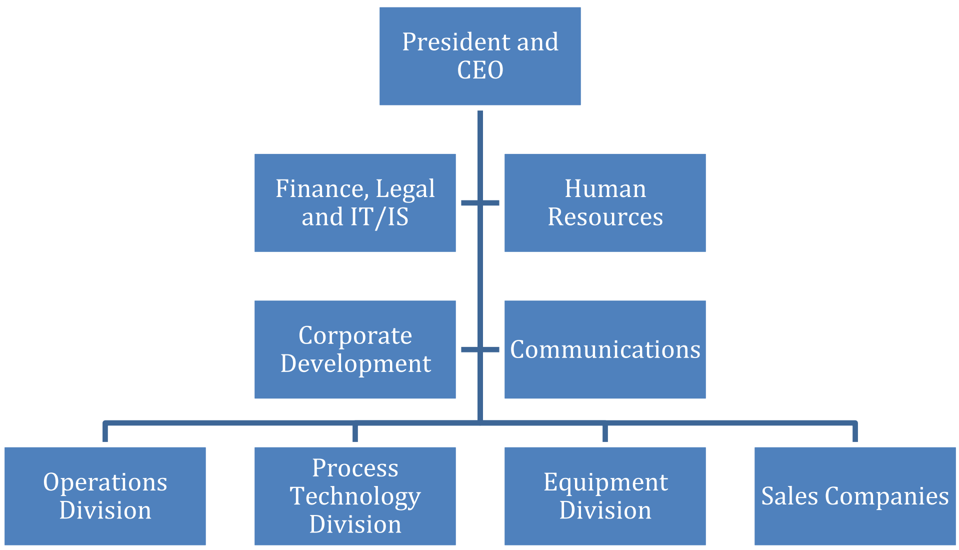

Figure 24. Alfa Laval's organizational structure

[39] Jaroslav Halac Manager - Mergers & Acquisitions Alfa Laval, personal interview on the 17th of March 2010.

The operations division contributes to increase the efficiency and delivery reliability, while at the same time creating economies of scale that result in reduced operating costs thanks to its centralization. The division has a global perspective with three regional purchasing offices located in India, China and Mexico and three central offices located in Sweden and Denmark. The centralization also consolidates the volumes which makes it easier to assess the group's overall material requirements. The production is centralized and based on manufacturing technology, product group and size. For example, regardless of their application, large separators are manufactured in Eskilstuna, Sweden; small separators in Pune, India; and medium-sized separators in Pune and Krakow, Poland. Alfa Laval has three primary distribution centers located in Tumba and Staffanstorp in Sweden and Kolding in Denmark. The company also has regional distribution centers in Indianapolis, USA; Singapore, Singapore; Shanghai, China and Shonan, Japan. (Alfa Laval, 2010)

The equipment division's customers are characterized by a well-defined and regularly recurring requirement of Alfa Laval's products. In most cases, sales are conducted through system builders and contracted companies as well as dealers, agents and distributors – direct sales to end-users are limited. The equipment division continuously increases its number of sales channels, since it is strategically important that its products are available through several channels worldwide. Given this focus on sales channels, it is natural that the division also strives to further develop and strengthen Alfa Laval's e-commerce offering. (Alfa Laval, 2010)

The process technology division serves customers that require specially adapted solutions to enhance the efficiency of their processes or boost their capacity. Sales are mainly conducted through contractors and the Alfa Laval's own sales companies and are made directly to customers. Alfa Laval combines expertise in its key technologies with solid knowledge about customer processes, and offers package solutions that cover everything from individual products to systems, complete solutions and by Alfa Laval argued efficient customer service. (Alfa Laval, 2010)

5.2.3 Alfa Laval's present markets

As mentioned before are Alfa Laval's operations based on three key technologies – heat transfer, separation and fluid handling. In *Figure 25*, each technology's respective percent of the total sales is shown. The three key technologies add up to 87%. Alfa Laval is the global leader in all three technology areas with more than 30% of the world market in heat transfer, 25 to 30% of the world market in separation and

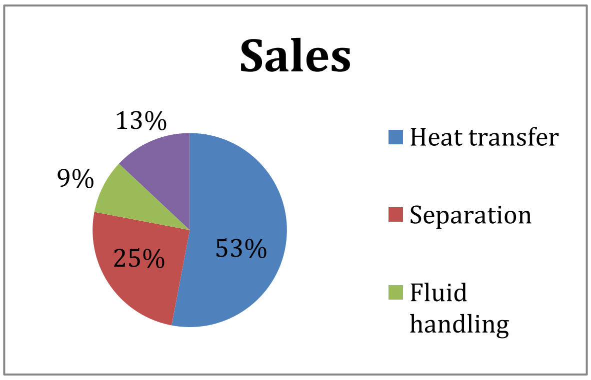

Figure 25. Alfa Laval's sales divided into technology group

10 to 12% of the world market in fluid handling. (Alfa Laval, 2010)

As mentioned above are the two divisions, Process Technology and Equipment, selling and marketing their products in eleven customer segments. Nine of these are divided by the two segments while the Parts & Service customer segment span across both of the divisions. The respective order intake is shown in *Figure 26* below, as well as the order intake on respective market. (Alfa Laval, 2010)

Order intake/customer segment	%
Parts & Service (EQD 14%, PTD 14%)	28
Process Industry	13
Comfort & Refrigeration	12
Sanitary	11
Energy & Environment	9
Marine & Diesel	9
Food	7
OEM	5
Fluids & Utility	3
Life Science	3

Order intake/geographic market	%
Other EU	32
Asia	31
North America	16
Other Europe	8
Latin America	6
Sweden	4
Other	3

Figure 26. Alfa Laval's order intake per customer segment

The market for flue gas treatment belongs to the energy & environment customer segment, which is positioned under the process technology division. The order intake in this segment accounts for 9% out of the total company, see *Figure 26*. The presence in Europe is intense with the head office based in Lund, Sweden. The total order intake of Europe accounts for 44%, with Asia on a strong second place with 31% and North America on third place with 16%. (Alfa Laval, 2010)

In *Figure 27* below are the market segments in which Alfa Laval's products are currently sold, within their three key technologies, marked as solid circles. The empty circles show the segments in which Alfa Laval's products previously where sold but for which the company made a strategic decision to dispose of its operations. (Alfa Laval, 2010)

Selected market segments	Comfort & Ref.	Marine & Diesel	OEM	Fluids & Utility	Sanitary	Food	Energy & Envir.	Process Industry	Life Science
Heat transfer	●	●	●	●	●	●	●	●	●
Separation		●	●	●	●	●	●	●	●
Fluid handling	○	○	○	○	●	●	○	○	●

The solid circles show the segment in which Alfa Laval's products are currently sold. The empty circles show the segments in which Alfa Laval's products were previously sold but for which the company made a strategic decision to dispose of operations.

Figure 27. Alfa Laval's selected market segments

As can be seen in *Figure 27*, within the segment of energy & environment Alfa Laval has chosen to be active in both heat transfer and separation but not fluid handling.

5.2.4 Alfa Laval's research and development processes

Alfa Laval with its predecessor AB Separator has been characterized by a focus on innovations and new way of thinking since its inception. E.g. the founder Gustav de Laval held 92 patents and was responsible for more than 200 inventions. Currently Alfa Laval holds more than 300 patents and in 2009 the investment in research and development was 654 million SEK which account for 2.5% of its sales. The vast investments in research and development are performed to maintain a leader position within the companies' three key technologies. (Alfa Laval, 2010)

The process of how Alfa Laval takes innovative ideas to the market is lined up in *Figure 28* below. In the first step to identify ideas, Alfa Laval works both externally with for instance universities and internally with structures enabling the employees to post ideas on the intranet. All ideas are then evaluated and compared to the business strategy before a decision is made to finance a project or not. The department corporate development is responsible for evaluating the ideas and brings it up to the general managers who make a go or no go decision. If a go decision is made, an organization is set up, which will run the project. The final step is to incorporate the new product into the line organization.[40]

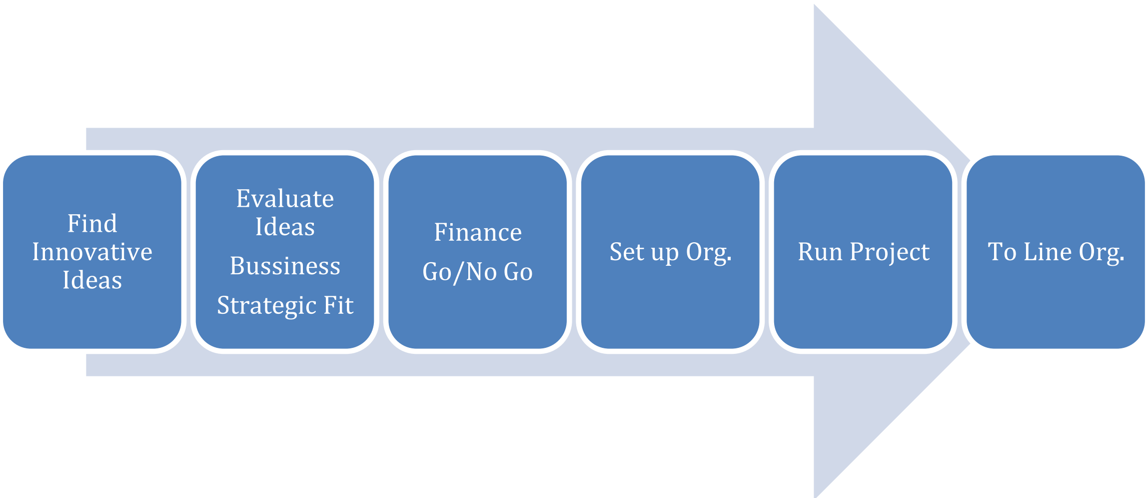

Figure 28. Alfa Laval's innovation process

[40] Tommy Norén Manager Technologies Alfa Laval, personal interview on the 7th of May 2010.

5.3 Appropriate Alfa Laval products

Alfa Laval holds a large product portfolio which spans over a broad spectrum of application areas. However, the most interesting products in relation to the relevant market are heat exchangers and separators. Within each product group, the most appropriate products has been chosen, based on technical requirements such as choice of material and maximum flow. The products within each product group will be presented below, starting with appropriate heat exchanging products.

Due to the fact that the heat exchangers will be exposed to, and operate in, a highly corrosive environment they need to be made out of a corrosive-free materials. Given the limitation of materials, the numbers of available plate heat exchangers are narrowed down to four different products; Alfa Nova, Alfa Disc, Alfa Rex and Compa Bloc.

5.3.1 Alfa Nova

Alfa Nova, see *Figure 29*, was at launch in 2003 a completely new type of plate heat exchanger; a plate heat exchanger made entirely of stainless steel. It is based on Alfa Laval's new bonding technology, Alfa Fusion, which is a method for joining stainless steel components together. Alfa Fusion technology is based on *transient liquid phase* (TLP) bonding, in order to join included components of the plate heat exchanger. The principle for TLP bonding is that stainless steel pieces which are contact with each other and at a temperature close to the melting point, has an affinity to bond together. The jointed material then consists of a material equal to the original pieces. As a result of this, Alfa Nova heat exchangers are products made of 100% stainless steel. (Alfa Laval, 2010)

Figure 29. The Alfa Nova 76

Application areas for the Alfa Nova

Due to the broad spectrum of Alfa Nova models, there is often an Alfa Nova product for each application. The main characteristic of the Alfa Nova series are however that it is highly corrosive resistant due to the corrosive-free choices of materials. It has a long life-span, high mechanical strength as well as being hygienic and safe. Alfa Nova is the potential choice where gasketed plate heat exchangers or shell and tube plate heat exchangers performance is not good enough, or where semi-welded or welded plate heat exchangers are not cost efficient enough. (Alfa Laval, 2010)

Typical application areas for the Alfa Nova are therefore:

- Compressor oil coolers
- Plate heat exchangers for refrigerator applications
- De-jonised water chillers
- Laser coolers
- Process cooling
- Vila stations, district heating systems
- Heat pumps (ground water)

Alfa Nova - Technical specification
The Alfa Nova is delivered with a 0.3 m^2 plate area. When the maximal amount of plates is utilized, the Alfa Nova has 81 m^2 large heat transfer area. The Alfa Nova is a small heat exchanger with a height of only 1.0 m. Given that it is a small heat exchanger, the maximal port size of the Alfa Nova is only 100 mm, which in turn heavily affect the maximal volume the heat exchanger can handle. From a temperature perspective the Alfa Nova works in the spectrum between -196°C to 550°C. (Alfa Laval, 2010)

Pros & cons

+ Copes with extremely low and high temperatures.
+ Long periods between failures
+ Corrosion resistance is equal to stainless steel of type 316
+ Compactness
+ Low weight
+ Broad span of application areas

- Somewhat limited in terms of pressure (compared with for instance the Alfa Disc)
- Cannot replace one heat plate, due to the fact that they are bonded together with Alfa Fusion.

5.3.2 Alfa Disc

Thanks to its circular design, see *Figure 30*, the Alfa Disc heat exchanger can withstand very high pressures. An accordion-shaped plate pack makes it less sensitive to thermal expansion as well as highly resistant to fatigue, both in terms of pressure and temperature. Its flexibility in terms of connection sizes makes the Alfa Disc a strong alternative for duties involving asymmetric flows. The Alfa Disc is furthermore fully welded and contains no gaskets. (Alfa Laval, 2010)

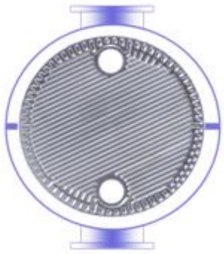

Figure 30. The form of the Alfa Disc 's heat plates

Application areas for the Alfa Disc
As mentioned above, Alfa Disc's circular shell makes it highly resistive against pressure as well as temperature, which in turn creates a broad spectrum of applications areas. The typical application area for the Alfa Disc is within general utility applications, with the biggest potential within industrial steam. (Alfa Laval, 2010)

Further examples of applications are provided below:

- Steam Heater/Condenser
- Steam generator
- High temperatures and/or high pressures
- Applications with huge difference in flow rate
- Gas Heating/Cooling
- Oil Heating/Cooling
- Application with needs to be cleanable on one side

Alfa Disc - Technical specification

The Alfa Disc is designed to heat transfer a wide scope of different mediums such as water, sea water, steam, oil, gas and air. The largest of the Alfa Disc models can have as many as 600 plates mounted. With a port size of 200 mm the Alfa Disc can handle significantly larger volumes compared to for instance the Alfa Nova described above. According to its specifications, the largest Alfa Disc can handle volumes as large as 10,700 l/h of water. Although, the temperature spectrum of the Alfa Disc is somewhat narrower compared to the Alfa Nova and does only stretch between 45^{0}C to 220^{0}C. It moreover adds a pressure drop of 10 psi. (Alfa Laval, 2010)

Pros & cons

+ Manage asymmetric flows
+ Highly resistive to pressure due to its rounded design
+ Fatigue resistant
+ Robust

- Narrow temperature span
- Rather large pressure drop

5.3.3 Alfa Rex

The Alfa Rex is the newest of the fully welded products in Alfa Laval's heat exchanger portfolio. The Alfa Rex consists of a laser welded pack of corrugated metal plates with portholes for passage of the two fluids between which heat transfer takes place, see *Figure 31*. The design has been achieved by laser welding the plates together one by one in alternate grooves to form a plate pack. The plate pack is installed in a frame consisting of a frame plate and a pressure plate compressed by tightening bolts. (Alfa Laval, 2010)

Figure 31. The Alfa Rex plate heat exchanger

Extended connections are located in the frame plate with bellow linings welded to the plate pack. The plate corrugations create high turbulence which results in very high thermal efficiency. This in turn leads to compactness and cost efficiency. The corrugations also support the plates against differential pressure and allow utilization of more expensive corrosion resistant materials, which is of high importance due to the application areas of this thesis. (Alfa Laval, 2010)

Application areas of the Alfa Rex

The Alfa Rex exists in two design, the TM10 and the TM20 were the latter is bigger than the former. As the Alfa Rex contains no gaskets as well as being fully welded, it is highly suitable for operations with aggressive mediums. It furthermore performs well during duties with cyclic temperature or pressure, where other heat exchangers meet their limits. The Alfa Rex therefore functions exceptionally well in applications where there are large flow variation, for instance in batch operating processes, start up and shut down processes or cleaning processes. (Alfa Laval, 2010)

Typical industries in which the Alfa Rex normally operates within are:

- Pharmaceutical industry
- Vegetable oils production
- Refrigeration
- Pulp and paper
- Marine & Power
- HVAC

Alfa Rex - Technical specification

The Alfa Rex is available in stainless steel, titanium and nickel. Its maximum flow rate is $700m^3/h$ with a heat transfer surface of $250m^2$. In similarity with the Alfa Disc, the Alfa Rex has a maximal plate connection size of 200 mm. It does however withstand temperature in the spectrum of -50°C to 350°C, which is broader than for the Alfa Disc, but narrower than the Alfa Nova. (Alfa Laval, 2010)

Pros & Cons:

+ Available in corrosive-free materials
+ Sustain high pressure and high temperatures
+ High accuracy in the predicted lifetime

- Expensive due to the choice of material, 200-400% more expensive compared to gasket plate heat exchangers.
- The heat plates cannot be replaced individually (since they are welded).

5.3.4 Compa Bloc

The Compa Bloc, see *Figure 32*, is a plate heat exchanger designed for corrosive environments with high volumes and high pressures. The product has been on the market since 2008 and the serie include a product span of seven different products. (Alfa Laval, 2010)

Figure 32. The Compa Bloc

Application areas of the Compa Bloc

The Compa Bloc has several different application areas and functions. Depending on the required outfall, the Compa Bloc could function as normal liquid-liquid heat exchangers, a one pass condenser, a reflux condenser, two pass condenser with inert subcooling, vertical condenser or a reboiler. In many applications where shell-and-tube heat exchangers historically have had a strong market position, the Compa Bloc captures market shares by being simpler, requiring less space and coping with high temperatures and pressures. (Alfa Laval, 2010)

Some typical application areas of the Compa Bloc are:

- ADU/VDU preheating
- Admine systems
- Tar sand
- Overhead condensers
- Feed preheaters
- Low-pressure pre-heaters
- District heating condensers
- Quench water cooling
- Ethylene production
- EO/EG production
- Proplylene production
- Butane condensing and reboiling
- Aromatics production
- District heating condensers

Technical specification

The Compa Bloc is the biggest of Alfa Laval's non-gasket heat exchangers. Over 500 plates can be mounted on a single Compa Bloc. In comparison to the earlier heat exchangers, the Compa Bloc can be delivered with 1,000 mm plate connections and thereby handle significantly larger volumes. However, due to confidentiality no other specific technical data on the Compa Bloc can be provided. (Alfa Laval, 2010)

Pros & Cons:

+ Removable frame
+ Less units in parallel
+ Less flanges
+ Multiple application areas
+ Design for duties with high volumes

- If titanium is used, the mechanical characteristics are heavily affected by temperatures above 100 °C.
- Large in terms of size

5.3.5 Clara

Clara, see *Figure 33*, is a solid ejecting separator designed for continuous high efficiency clarification of beverages and wine prior to final filtration. The unique completely sealed design not only gives an extremely gentle acceleration of shear-sensitive agglomerates: it also avoids pick-up of oxygen and prevents loss of volatile aromas and CO_2. Together with the geometry of the separator, the completely sealed inlet leads to maximum separation efficiency. Clara meets the high hygienic demands of the food industry and is designed for cleaning-in-place and is easily included in the automatic cleaning systems of the process plant. A further advantage with the design is the low power consumption. (Alfa Laval, 2010)

Figure 33. The separation model: Clara

Application areas

The Clara is specially designed for various process steps in the production of wine, fruit juice and tea. It is used for removing suspended solids with a particle size of 0.4–200 µm. The solids content in the feed is normally in the range of 0.1–1% by volume, but Clara can handle larger concentrations as well.

Clara is specifically suited for clarification of the following products:

- White grape must (free run and press juice).
- Young wine (still and sparkling).
- Matured wine.
- Fruit juices (deciduous, citrus and tropical)
- Coffee and tea extract.

Technical Specification

The maximum throughput capacity of Clara is 75 m^3/h. The real possible throughput will however depend upon a number of factors, such as the amount and type of solids, viscosity and the required degree of clarification. The Clara's bowl speed rotates with a speed of 4800 rpm and can contain as much as 38 liters.

Pros & Cons:

+ Low power consumption
+ Small footprint
+ High accurate discharge volume
+ Erosion protected bowls
+ High separation efficiency

- Low volume capacity.
- Mostly tested within the food industry rather than industrial applications.

5.3.6 Pure Vent

Pure Vent is a high speed separator that removes oil and particles from crankcase gas on marine diesel engines, which is an essential byproduct of all internal combustion engines. The separator is a compact installation that consists of a stack of 185 rotating composite discs driven by an electric motor, see *Figure 34*. The stack is enclosed in aluminum housing and has a size of 30l for any engine size. There is no negative impact on engine performance and no need for maintenance or inspection during the first two years of operation. (Alfa Laval, 2010)

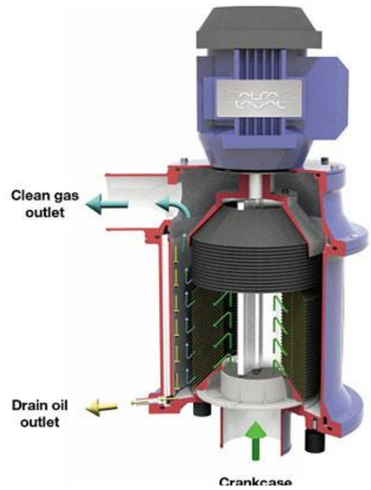

Figure 34. The Pure Vent separator

Unclean crankcase gas enters at the bottom of the separator, and continuous into the disc stack. Centrifugal forces press out the oil and soot between the discs, allowing it to be collected on the inside of the disc stack housing. This leaves a virtually oil-free air, which can be released into the atmosphere. (Alfa Laval, 2010)

Application areas

Pure Vent is developed in cooperation with Wärtsilä from the land based solution Alfdex that has cleaned crankcase gas on trucks and buses since 2002. Today Pure Vent is only available through Wärtsilä as part of an engine or as a module for retrofit. However, other engine makers are testing the Pure Vent and will probably deliver a similar product in a near future. (Alfa Laval, 2010)

Technical specification

Pure Vent has a maximum capacity of 800m3/h and a nominal capacity of 150m3/h, see *Figure 35* below. As can be deduced from *Figure 35* the cleaning efficiency is 98% at a nominal flow and the noise level of 78 dBA. The size is 70 x 34 x 40 cm which gives a total weight of 39 kg. The separator has a rotating speed of 7,200 rpm, a maximum power consumption of 1.5 kW and a start time of 15 seconds. It needs intermediate service every 4,000 running hours and major service every 16,000 hours or five years, whichever comes first. (Alfa Laval, 2010)

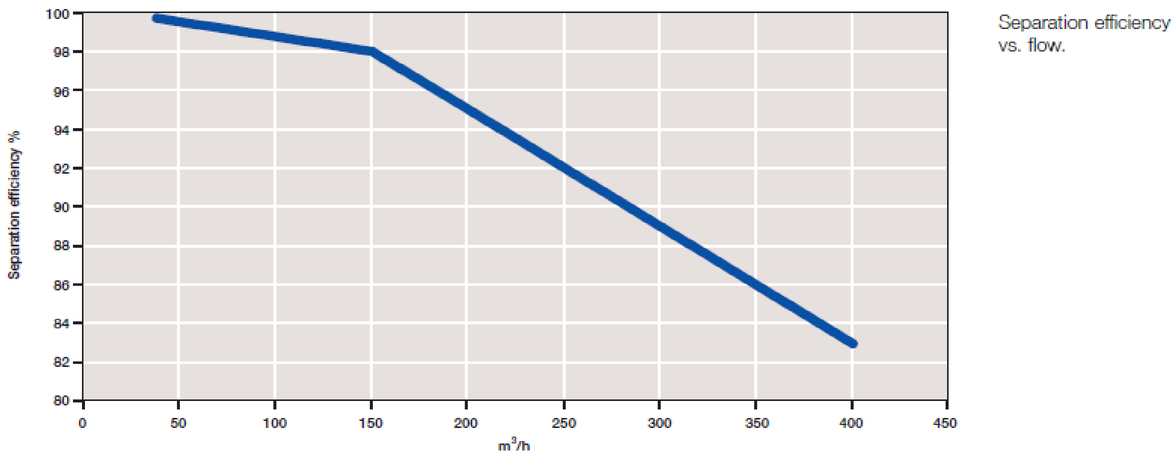

Figure 35. Pure Vent's efficiency at different flows

Important for this thesis is not only the flow but also the temperature and how efficient the separator is at separation small sized particle. The separation efficiency in terms of small particles is shown in *Figure 36* below. Particles down to 0.3 microns can be efficiently removed at 98% efficiency and particles at 0.2 microns with 80% efficiency. Pure Vent is however limited in terms of the inlet temperature of the gas. The maximal temperature of the inlet gas the Pure Vent can handle is 80°C.

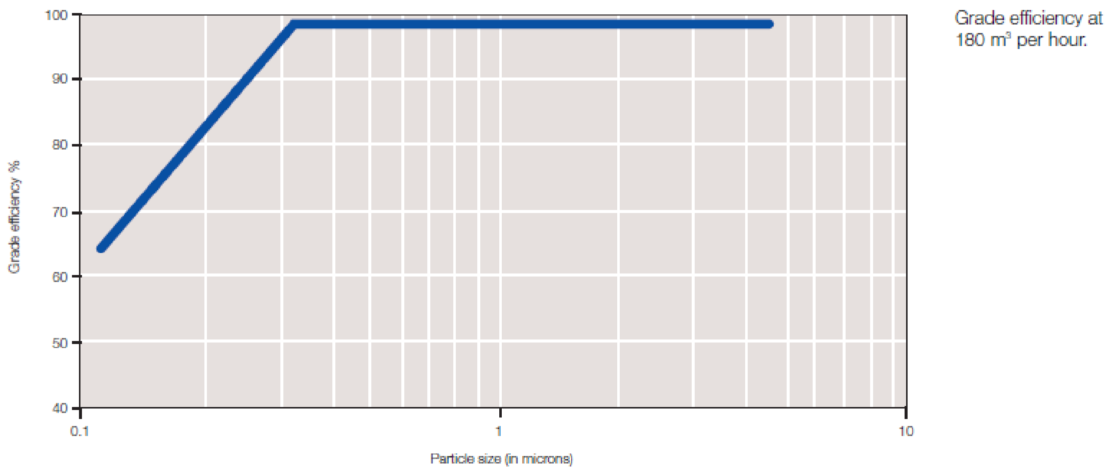

Figure 36. Pure Vent's particle size efficiency

Pros & Cons:

+ High separation efficiency of small particles.
+ Small footprint
+ Long intervals between maintenance
+ Is designed for gas as medium

- Low volume capacity.
- Low maximal temperature
- Long start up times

5.4 Analysis of Alfa Laval's potential for entering the market

Below follows an analysis of Alfa Laval's potential to enter the market for exhaust gas treatment, given their resources and capabilities discussed initially in this chapter.

5.4.1 Strategic fit

The principal basis for firm strategy and the primary source of profitability is accordingly to Grant (2008) resources and capabilities. Grant (2008) further states that firms should exploit their unique resources and capabilities in order to create competitive advantages. This will express the degree to which an organization is matching its resources and capabilities with the opportunities in the external market.

First of all, the entry of a new market needs to be evaluated against the strategy of the firm. The overall strategy of Alfa Laval is to create a profitable growth of at least five percent annually, either through acquisitions or organic growth within the company's selected market segments (Alfa Laval, 2010). One of the market segments that Alfa Laval has chosen to be active in is *energy & environment* which includes the investigated area of this thesis. Within the market area two of the three key technologies are currently sold, namely the heat transfer technology and the separation technology. Moreover, the relative aggressive growth rate compared to competitors demands that the new potential markets are large in order to be considered worth entering.[41]

Furthermore one of Alfa Laval's aims is to limit the environmental impact. The energy market has generally a negative reputation from an environmental perspective which cause that firms associated with the industry often becomes target for negative publicity. However in this case, the solution will decrease the emissions and/or increase the efficiency. With the right marketing efforts the risk of being associated with a negative environmental impact could be reduced and instead create a positive view with the focus to limit the environmental impact.

5.4.2 Resources and capabilities

When studying Alfa Laval´s organizational structure *tangible, intangible* and *human resources* are found which needs to be outlined, since they accordingly to Grant (2008) provides the basis for an organization's capabilities.

According to Grant (2008) it exist two types of tangible resources: financial and physical. In terms of financial resources, Alfa Laval has several times proven its financial strength. The latest example is the six acquisitions conducted during 2009, despite the economic downturn. Furthermore, a maintained operating margin above the goal of 15% over a business cycle further illustrates the financial strength of the company.

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[41] Tommy Norén Manager Technologies Alfa Laval, personal interview on the 18th of Feb. 2010

In terms of tangible physical resources, Alfa Laval owns both production facilities and distribution centers. Alfa Laval's production facilities are top of the line in order to stay ahead of competition. Moreover are the distributions centers located all over the world in order to stay close to the market. In combination with centralized purchasing offices that contribute to increase the efficiency, Alfa Laval can be argued to have strong physical resources.

Accordingly to Grant (2008) there are three categories of intangible resources: technology, reputation and culture. Technology is a strong resource within Alfa Laval, which is shown by their patent portfolio that consists of more than 300 patents. Moreover are the investments of 654 million SEK in research and development projects during 2009 a clear indication that Alfa Laval prioritizes technology and wants to stay ahead of competition.

Reputation is also a strong resource for Alfa Laval. Since the founding in 1883, the company has developed from a small niche player to a large global player. During this time period, the brand Alfa Laval has developed to become one of the company's key resources. The brand is furthermore well-known within the industry and is associated with good quality and state of the art performance in terms of both products and services. The new graphical expression from 2002 has shown successful regarding expressing the company's new strategy while at the same time maintaining the history and reputation of the brand. The history is important since it provides the customers with a sense of reliability and robustness.

The culture of the company, which is the last of Gant's (2008) three intangible resources, has been shaped and affected by Alfa Laval's history as an innovative player. Alfa Laval was founded by a true entrepreneur, Gustav de Laval, who was responsible for more than 200 inventions. The spirit of de Laval as well as the entrepreneurship still colors Alfa Laval, even though the company is much larger today. Moreover, the authors of this thesis felt a positive encouraging attitude towards new ideas and innovation within the organization and when interviewing employees.

Finally, in terms of human resources, Grant (2008) formulates categories such as specialized skills and knowledge, capacity for communication and collaboration, and motivation. Regarding specialized skills and knowledge Alfa Laval are considered well-equipped. The company withholds a leader position in their three key technologies and is contently launching new solutions in order to improve the costumer's processes. The customers demand a close relationship and presence on the market in order for Alfa Laval to have the required skills and know-how of their processes. Without the skill and knowledge required, Alfa Laval would not be able to stay competitive.

The capacity for communication and collaboration within Alfa Laval could however be improved. The organizational structure of the company causes a natural division within the company, but the necessary communicative and collaborative pathways are not always in place. One example is that Alfa Laval has been increasing its growth through acquisitions rather than through organic growth.[42]

The motivation of the employees at Alfa Laval is estimated to be normal for a company of its size. The company uses both intrinsic as well as extrinsic rewards to increase their employee's motivation. Therefore, it is no reason to believe that their employees should be more or less motivated compared to similar companies.

In order to further evaluate if Alfa Laval's resources and capabilities can match the opportunity in the external environment, an analysis together with Norén[43] was performed. The analysis weighted Alfa Laval's resources and capabilities based on importance when creating a competitive advantage and their relative strength compared to the existing players of the industries, provided in chapter 3. The result of the analysis is shown in *Figure 37* below.

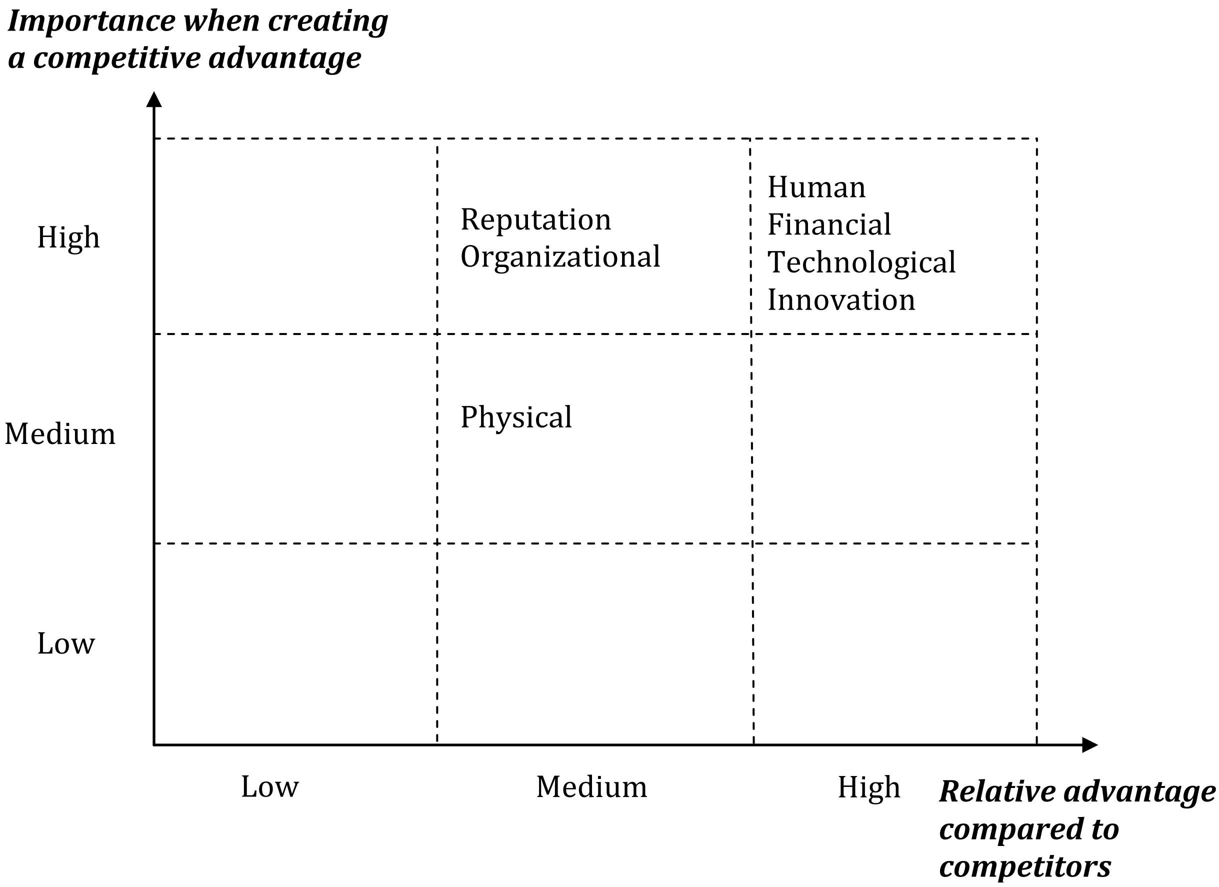

Figure 37 - Alfa Laval´s resources evaluated to the business opportunity

[42] Tommy Norén Manager Technologies Alfa Laval, personal interview on the 6th of Feb. 2010.
[43] Tommy Norén Manager Technologies Alfa Laval, personal interview on the 7th of May. 2010.

Grant (2008) states that the resources at hand set the limitations for the strategic actions a company can undertake. Grant (2008) further states that superior profitability is better achieved by creating a competitive advantage by implementing a strategy that exploits the firm's unique resources and capabilities. Based on that rationale, Alfa Laval's resources and capabilities are suitable for both heat recovery and mist elimination of flue gases.

In chapter 4, the general characteristics as well as the boundary conditions of the flue gas treatment industries was provided. In order to find out if Alfa Laval's existing resources and capabilities will correspond to, and function with, those boundaries an evaluation of the company's resources and capabilities in relation to the specific industries is needed. One of the most valuable resources Alfa Laval possesses is their products and know-how. A vital question is therefore if the different products mentioned in this chapter can be used in order to enter the heat recovery and/or the mist elimination industry.

5.4.3 Alfa Laval's resources and capabilities suitable for the heat recovery

Regarding the heat recovery market four relevant products where found in Alfa Laval's portfolio; Alfa Nova, Alfa Disc, Alfa Rex and Compa Bloc. An evaluation of these products in combination to the requirements of the market will now be performed.

Alfa Nova is a highly corrosive plate heat exchanger that can take temperatures as high as 550°C. This sounds promising but the product is heavily limited in terms of port size and thereby volume of flue gas. Given that power plants produces vast amounts of flue gases a port size of 100 mm is simply not enough.

The *Alfa Disc* and *Alfa Rex* do both cope with the temperatures of flue gases and have a port size of 200 mm, which is twice as large as the Alfa Nova. A port size of 200 mm is however still not enough as the amount of gas could be as large as 150,000m^3/h if the power plant has an effect of 30 MW, see *Figure 20* at page 35. Furthermore are both the Alfa Disc and Alfa Rex constructed for fluid mediums and not gases.

The *Compa Bloc* is produced with a maximal port size of 1,000 mm. This enables the heat exchanger to cope with the vast amount of flue gas that is produced by a smaller power plant, up till about 15 MW. One of the Compa Bloc's applications areas is furthermore to be used as a condenser. The possibility to combine the application areas of heat transfer and condensation makes the Compa Bloc Alfa Laval's most suitable product within heat recovery of flue gases.

However, as shown in the industry analysis, the market for heat exchanging of flue gas from biomass boilers using condensation is mature. For instance, Börjessons[44] mentions

[44] Tomas Börjesson CEO Radscan, personal interview on the 17th of Feb 2010.

that the company Radscan takes orders with a negative profit as mentioned earlier. The statement indicates that the market is characterized by heavy competition. One reason may be that during the past years most of the boilers, particularly in Sweden where the district heating system is widespread and has a sufficient low return temperature, already have been equipped with condensing technique.

The coal fired stations do generally not lower the temperature of the flue gas below 120-140°C. The temperature of the flue gas is thereby higher than the dew point for water and condensation would work even if the moisture level of the fuel is low. Although, by not lowering the temperature further, the dew point for sulfur acid steam is avoided and problems with corrosion do not appear. However, if condensation would be used on coal fired power plants, these potential problems with corrosion could be solved by introducing polymeric material into the chimney and replace pipes that are affected by water or sulfur acid with corrosive-free materials.

One major issue is however to find a receiver of the amount of low temperature heat a coal power plant would produce using condensation. A normal bio-fuel plant has an effect of about 20 MW and the produced heat often covers the demand of the local district heating system. A 500 MW or 1,500 MW coal fired power plant would produce such enormous amounts of heat that the whole supply-and-demand curve for heat would shift, causing a decrease in price which in turn erases the profitability of the market.[45] The district heating systems are furthermore often distant from the coal fired stations and the temperature is too low to use in existing gas turbines. This is of course a very interesting area for the future, but the time frame is too long for being considered in this thesis.

The lack of boilers left to equip with condensation technology that combust bio-fuels in combination with the negative effects on utilizing condensation on coal fired power plants makes the industry unsuitable for Alfa Laval. Even though the Compa Bloc could have been used in such applications, it would be hard to gain competitive advantages against the already existing and established solutions on the market.

5.4.4 Alfa Laval's resources and capabilities suitable for mist elimination

As shown earlier in this chapter, Alfa Lava possesses centrifugal separators that could be interesting to evaluate for mist elimination. Clara and Pure Vent are two such products that will be further analyzed in relation to how the present mist eliminating market and its boundaries.

The centrifugal separator *Clara* is a highly efficient separator for fluid mediums. A solution using Clara would however require some sort of preceding wet scrubber, in order to change the medium which the particles exists within from gas to water.

[45] Stefan Åhman Technology Manager - Dry gas absorption Alstom, personal interview on the 20th of April 2010.

Although, such solutions are rare on the market and do at the moment only exist in the northern parts of Europe where condensation of the flue gas from bio-fuels are utilized. Due to lack of boilers left to equip with condensation technology, a solution for mist elimination using Clara would be hard to make profitable. Moreover is the centrifugal separator Clara more expensive compared to the established filter solutions on the market[46].

Pure Vent on the other hand is a centrifugal separator, which eliminates particles directly from the gas. In other words, there is no need to go via the water phase and condensation is thereby not required. Pure Vent can moreover eliminate particles with a size as low as 0.2 microns which is comparable to the existing filter solution in terms of performance. The negative aspect of Pure Vent is however the nominal capacity of $150m^3/h$, which is far below the required volumes. Although, the size of the separator is at the moment adapted for crankcase gas on marine diesel engines. Königsson[47] and Manelius[48] state that there is no problem to redesign the separator in order to enable it to handle larger volumes of gas. Another solution would be to set a number of Pure Vents in parallel to be able to cope with the higher flows. Evidence of the possibility for such a solution is found in the small competitor 3nine that recently entered the market with a similar product[48].

As shown in the empirical chapter, the market for mist elimination is growing and is dominated by fabric filters and electrostatic filters. The market is vast and a rough estimation states that there are about 18,000 boilers only within Europe. In order to meet the environmental legislation provided by the EU commission, these boilers are required to have mist elimination equipment installed. The present legislations demand a maximal emission value of 50 mg/Nm^3 for new plants and 100 mg/Nm^3 for existing plants. However, these legislations change with time and it is important to notice that the legislative demands currently only are weight specific. If the legislations were set based on the amount of particles rather than the size of the particles, the focus would shift toward small particles that require more efficient separation solutions. All these factors speak in favor for a continuous growth of the mist elimination market, which is a market in which Alfa Laval could compete using a developed Pure Vent solution.

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[46] Tom Manelius Manager Process Analyst & Design Alfa Laval, personal interview on the 17th of Jan 2010.
[47] Staffan Königsson Process Analyst and Design Alfa Laval, personal interview on the 26th of March 2010.
[48] Tom Manelius Manager Process Analyst & Design Alfa Laval, personal interview on the 25th of March 2010.

5.5 Summary of Chapter 5

Chapter 5 aimed at answering the second research question; *"What internal resources and capabilities does Alfa Laval possess that can be used or developed in a potential system solution for flue gas treatment?"*

The answer to that question was provided by adapting the resources based view. The analysis showed that Alfa Laval had a lot of suitable resources in terms of know-how and R&D. Alfa Laval furthermore have a well implemented structure for fostering new innovations and a strategy which promotes expansion. Although, even if the strategy promotes the company to grow organically, it is more characterized by external growth through acquisitions. Moreover the company withholds an established and global network of sales channel and a brand which is well-known in terms of quality and performance.

In an analysis of Alfa Laval's relative advantage compared to competitors and how important those are when creating a competitive advantage, Alfa Laval scored high from both aspects in terms of human, financial, technological and innovative strengths. In terms of reputation, organizational structure and physical assets, Alfa Laval was ranked in an equal position compared to their competitors. Although, reputation and organizational structure was considered more important than physical assets when creating competitive advantages, this since physical assets often can be bought.

At a closer look at Alfa Laval's product portfolio, their gas separator Pure Vent is found to be interesting from a flue gas perspective. The Pure Vent is designed to remove oil and particles from crankcase gas on marine diesel engines, but could with modifications be redesigned to clean particles from flue gas at power plants. At the moment, the Pure Vent can clean particles as small as 0.2 μm, but is limited in terms of gas volume.

6 ARE THERE POTENTIAL BUSINESS OPPORTUNITIES?

Based on the information and analysis provided in chapter 4 and chapter 5, chapter 6 investigates the potential business opportunity for Alfa Laval to enter the market for mist elimination of flue gases, given their internal resources and capabilities. In that sense, chapter 6 combines all of the three cornerstones which were discussed in the introduction of the report and studies their intersection, see *Figure 38* below.

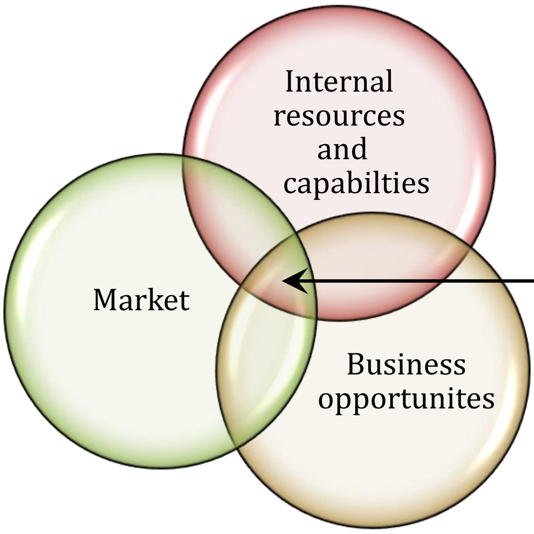

Figure 38. The focus of chapter 6

Chapter 6 aims at answering the third and final research question; *Are there any potential business opportunities for a combined system solution of heat recovery and particle separation of flue gas for Alfa Laval?"*. Chapter 6 furthermore aims at providing Alfa Laval with information for a go or no go decision regarding entering the market for mist elimination of flue gases or not.

6.1 Literature review

In consensus with the previous chapters, chapter 6 begins with a literature review. The literature review focus on theory regarding adoption of innovations, customer segments and obstacles corporation faces when entering new markets and developing new products.

6.1.1 Diffusion of innovations

Adopting a new idea is often very difficult even if the idea has obvious advantages. Many innovations require a lengthy period from that they are available until they are widely adopted in the marketplace. The primary objectives of diffusion theory are to understand and predict the rate and pattern of an innovation's diffusion.

According to Rogers (1995) the diffusion depends on a potential adopter's perception of the technology. Rogers (1995) introduces five factors that are important characteristics of innovations in order to explain their adoption rates. These factors are *relative advantage*, *compatibility*, *complexity*, *trialability* and *observability*.

Relative advantage concerns the degree to which a technology is perceived as better than the technology it supersedes or competes with. Relative advantage can be measured in economic terms, satisfaction, convenience or social prestige. As there are several factors which a customer evaluates a products relative advantages by, it is not only the objective advantages that matters. What instead mainly matters is what the customer perceives as advantageous. (Rogers, 1995)

Compatibility refers to the degree to which a technology is perceived as being consistent with the existing skills, needs, past experiences, norms and practices among potential adopters. A new value system is often required before an adoption of an incompatible technology can take place. (Rogers, 1995)

Complexity concerns the degree to which a technology is perceived as easy to use. If the technology cannot easily be understood, the adopter is required to develop new skills which will extend the adoption process. (Rogers, 1995)

Trialability refers to the degree to which experiments can be carried out on a limited basis and the last factor, observability, refers to the extent the results of a technology is visible to others. (Rogers, 1995)

Innovations with a high degree of perceived relative advantage, compatibility, trialability, observability and low complexity will be adapted more rapidly than other innovations. Accordingly to past research, these five factors are the most important characteristics of innovations in explaining the rate of adoption. (Rogers, 1995)

The adoption of innovations often follows an S-curve, see *Figure 39* below. The S-curve illustrates an innovation's development in terms of performance relative its lifetime. In the beginning of a successful innovation there are often only a few companies working with products or services using the innovation. Therefore, the performance development is rather slow and drifting. As more companies become interested in the innovation and the market becomes larger, the development takes off creating a steep increase in performance. As the product gets more mature and get closing in to the end of its lifecycle, the development decreases as investments are put into other, newer products. (Moore, 1998)

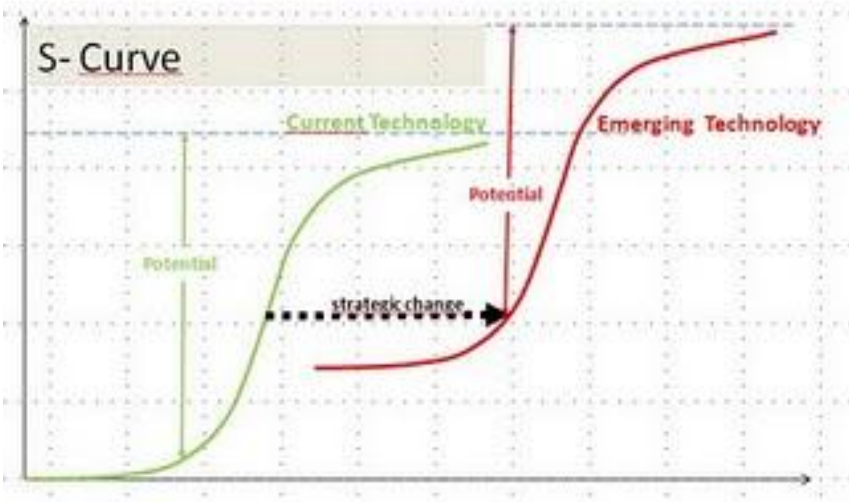

Figure 39. An illustration of a product's S-Curve

When the adoption follow the S-curve, the distribution curve of adopters follows a normal distribution, as shown in Figure 40 below. The adopters can then be divided into five categories: *innovators, early adopters, early majority, late majority* and *laggards.* (Dorf & Byers, 2008)

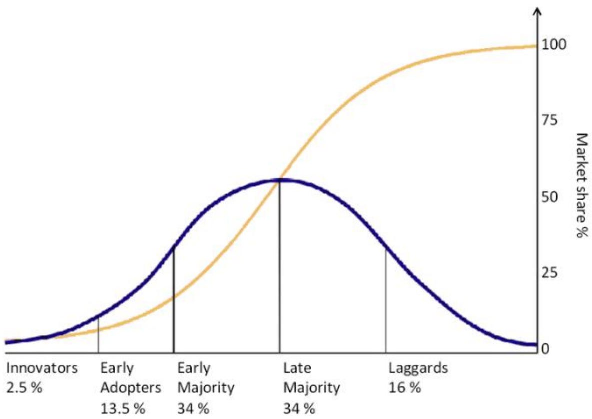

Figure 40. The five categories of adopters in relation to a products development

However, upon closer examination, Moore (1998) states that a *chasm* exists between the early adopters and the early majority, see Figure 41. The chasm is caused by radically different demands in terms of the value offer between the two segments. The early adopters are buying some kind of change agent for technology and performance, while early majority wants a complete and tested solution. The early adopters furthermore expect to get a jump-start on the competition by being first in the industry to implement the new innovation. They are also prepared to bear with the bugs and glitches that are common in product's early phases. In contrast to the early adopters, the early majority wants to improve existing operations through integrating the new technology without function as a debugger of someone else's problems. Moreover is the problem further increased as references are critical for the early majority and other members of the early majority is considered to only proper source of reference. In other words are the early adopters not a good reference group for the early majority and a catch-22 situation occurs. (Moore, 1998)

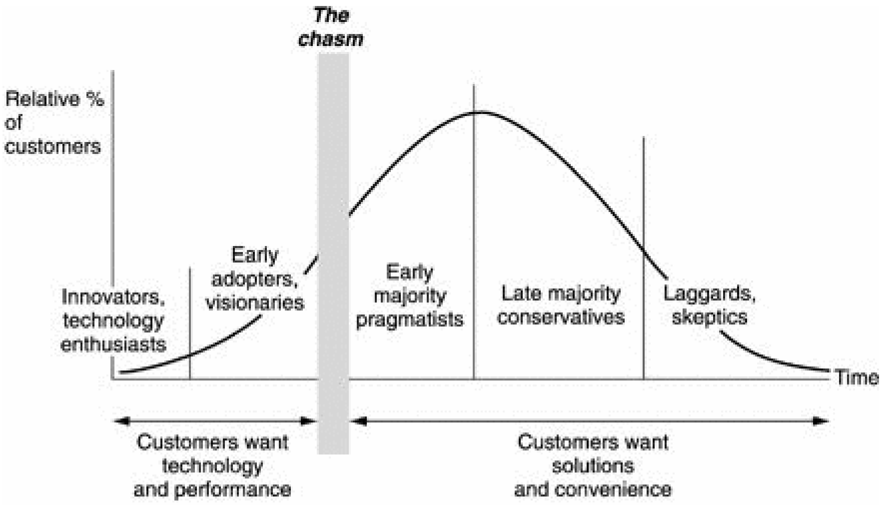

Figure 41. An illustration of the chasm between the early adopters and early majority

6.2 Analysis of the business opportunity

In order to evaluate if centrifugal separation of flue gas would be a potential business opportunity for Alfa Laval, Rogers' (1995) five factors can initially be used. The market for mist elimination and particle separation is at the moment characterized by filtration. Electrostatic filtration and filtration using fabric filters constitute more or less the whole particle separation market. Entering such a market with a new innovation such as a developed version of Alfa Laval's Pure Vent or 3nine's existing solution Olga would challenge the established filtration solutions. By comparing the innovation's relative advantage, compatibility, complexity, trialability and observability, an initial analysis of the innovation's chances to become adopted can be withdrawn. By also comparing the potential market to the resources and capabilities of Alfa Laval it is possible to analyze if the innovation's market is big enough, but also if it is in line with the company's strategy.

6.2.1 Centrifugal separation's changes of getting adopted

As argued by Rogers, there are several different types of relative advantages. Some relative advantages are connected to the product's or solution's technical performances while others are connected to the financial advantages. However, since Alfa Laval's Pure Vent primarily is designed for mist elimination of exhaust gases from engines and not flue gas from power plants, the exact performance of a developed Pure Vent is somewhat unclear. Although, findings which are based on interviews with both Manelius[49] and Königsson[50] at the R&D department for separators at Alfa Laval in

[49] Tom Manelius Manager Process Analyst & Design Alfa Laval, personal interview on the 25th of March 2010.

Tumba shows that there are no major issues regarding redesigning Pure Vent for flue gas handling. According to Manelius[51], the present design of the Pure Vent separator is based on the demands from its only customer; the Finish engine manufactorer Wärtsilä. Provided that an application area is found, Manelius[51] argues that there would be no problem to redesign Pure Vent, for instance to make it larger in order to manage larger volumes.

A product which is present on the market today is however 3nine's Olga. Olga uses a centrifugal separation technique for gases which at the moment makes it unique. According to both Manelius[51] and Königsson[50], a developed Pure Vent would perform in similarity or even better than 3nine's Olga, which in turn makes Olga a proper product for a comparison. If the technical performances are compared between filtration of flue gases and centrifugal separation of flue gases, there are some resemblances but also some differences.

The biggest difference concerns the manageable volumes of flue gas with the two systems. Both electrostatic filters and fabric filters can easily manage flue gas volumes of over 1,000,000 m^3/h[52,53], while Olga only can manage about 4,000-5,000 m^3/h of flue gas per separator (3nine, 2009). If the centrifugal separation technique is used and larger gas volumes than 5,000 m^3/h needs to be managed, several separators must be parallel connected in order to add up to the higher volumes of gas. In that sense, the centrifugal separators could at the moment only challenge the established filtration techniques at smaller power plants that produce less volumes of flue gas. Notable is however, that 85% of the boiler population is below 30 MW which would be to an advantages for Alfa Laval in this case.

A resemblance between the filtration technique and the centrifugal separation technique is the efficiency of the particle separation and how small particles each technique efficiently can separate. The filtration technique with its electrostatic filters and fabric filters has an efficiency of 99.5% and can capture particle as small as 0.1 µm. The centrifugal separation technique on the other hand separates particles down to 0.3 µm with 98% efficiency. The efficiency of the centrifugal separation is though tightly connected to the gas volume. As the volumes goes up the efficiency goes down, which ones again provides a clear argument for Alfa Laval to focus on boilers with an effect less than 30 MW.

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[50] Staffan Königsson Process Analyst and Design Alfa Laval, personal interview on the 26th of March 2010.
[51] Tom Manelius Manager Process Analyst & Design Alfa Laval, personal interview on the 25th of March 2010.
[52] Peter Wieslander Technology Manager - FF process Alstom, personal interview on the 20th of April 2010.
[53] Per Johansson Technology Manager - ESP Mechanical Alstom, personal interview on the 20th of April 2010.

If the financial aspects of the technique's relative advantages are compared, the centrifugal separation has strong advantages over filtration. According to 3nine, their Olga separators cost only half of what an equivalent filtration solution would cost, even if they use three parallel connected Olga in order to cope with the flue gas volumes. 3nine further claims that solutions using centrifugal separation only requires one fifth of the space compared to equivalent filtration solution. The footprint of centrifugal separation is in other words considerable less, which often is a key factor when installing mist elimination equipment using retro fit kits. Due to the fact that the boiler, turbines and other parts of the boiler system already are in place, the retro fit kit more or less needs to fit in a predefined space in between. (3nine, 2009)

One final relative advantage with the centrifugal separation technique in terms of financial benefits is the maintenance costs. As centrifugal separation does not have any filters or other parts that need to be replaced with specific intervals, the only maintenance needed is a quality verification which with advantages can be scheduled during the power plant's two week long maintenance stop during the summer.

Moving on to Rogers' (1995) second factor, compatibility, it is obvious that filtration has an advantage over centrifugal separation as it is the established technique at the moment. Changing separation technique might need some time for the power plants to adjust to, but since it is only a complementary process to the power plant's core processes it is likely to face less inertia compared to for instance a change of boiler or turbine. As the particle separation is a process which more or less runs in the background of the core processes, the plant's personnel does not need to have any specific knowledge or skills regarding the separation processes when it is installed and running. Although, in order for the separation technique to truly challenge the established filtration techniques, it will be important to influence the plant's purchasing procedures, making them aware of the new technique. There could moreover also be some geographically differences regarding the compatibility. The norms and practices among potential adopters can differ between countries. An example of this is India, which historically has had a rough time adapting to fabric filters, and therefore still uses electrostatic filters almost exclusively[54]. India would therefore be a poor choice to initially focus at, and other markets should be aimed at in order to cross the chasm.

As discussed above, the centrifugal separation of the flue gases from power plants would become a secondary process. The only maintenance required is the one performed under the scheduled maintenance break, which furthermore could be conducted by Alfa Laval themselves and thereby become an additional service. From the perspective of Rogers' third factor, complexity, this means that the power plants would not experience

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[54] Per Johansson Technology Manager - ESP Mechanical Alstom, personal interview on the 20th of April 2010.

any differences in terms of complexity. From the power plant's perspective a centrifugal separation would be installed in resemblance with the filtration technique, it will separate in resemblance with the filtration but cost less, take less space and reduce the maintenance costs. A centrifugal separator would furthermore take away the need of cyclones which is commonly used prior for instance fabric filters[55]. In that sense, centrifugal separation has lower complexity compared to filtration which opens up for a more rapid adaption.

The trialability and obervability, which are Rogers' fourth and fifth factors, are two factors which work to the filtration technique's advantage. As there already are numerous of filters assembled at power plants all around the world, the observability is enormous. In terms of trialability, filter separation of flue gases is somewhat redundant as there are so many real cases to study rather than experiments. The centrifugal separation on the other hand does also have a large installed base, but in other application areas. In that sense, the centrifugal separation technique has a good trialability and observability. The trialability and observability further increases thanks to 3nine's Olga, which makes it possible to test the technique and its performance in real environments.

6.2.2 Is the new market suitable for Alfa Laval?

As mentioned earlier in chapter 5, Alfa Laval aims at increasing their invoice with 5% annually. In order to achieve such a steep increase, new potential markets needs to be large in order to be interesting for Alfa Laval. As mentioned in chapter 4, there is a large variety on the market in terms of sizes of boilers and thereby the flue gas system as such. It will therefore be essential for Alfa Laval to find a potential entry to the market where they can achieve either large margins or sell large amount of products.

If Alfa Laval would choose to focus on larger boilers, two difficulties primarily arises; (1) the performance characteristics of the centrifugal separation technique cannot handle large volumes of flue gas at the moment and (2) the procurement procedure of large boiler system is characterized by heavy competition and small margins due to the OJEC tender process. Therefore, given the distribution of boilers on the market today, the best opportunity for Alfa Laval is to focus on smaller boiler system and instead sell large amounts of centrifugal separators, and by doing so achieve economies of scale. In order for Alfa Laval to reach the sales volumes required to accomplish economies of scale, they would need to focus on small sized boilers in the span between 0-30 MW which contributes 85% of the boiler market (Svensk Fjärrvärme, 2010).

By focusing on boilers with an effect below 30 MW, Alfa Laval would gain access to a market which according to the rough estimation provided in appendix I corresponds to

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[55] Peter Wieslander Technology Manager - FF process Alstom, personal interview on the 20th of April 2010.

at least 90,000 boilers worldwide. In the estimation, an assumption is made regarding how often a power plant invests in a new mist elimination technology. If the power plants invest every forty year, there are 2,300 sales opportunities annually. Given that Alfa Laval could capture one tenth of the market share with the centrifugal separation technique, that market share would be worth about 600 million SEK annually. The market for mist elimination of flue gases could therefore with ease be regarded as large enough for Alfa Laval. For more detailed information regarding the market estimation, see appendix I.

6.2.3 Future potential for centrifugal separation

Centrifugal separation of flue gases is still in its starting block. The immaturity of the technique has both its pros and cons. One of the cons with the new technique regards that it still has a lot to prove as it is rather untested, which has been discussed earlier in this chapter. However, on the positive side the new technique still has a big potential to develop and by doing so become even more competitive.

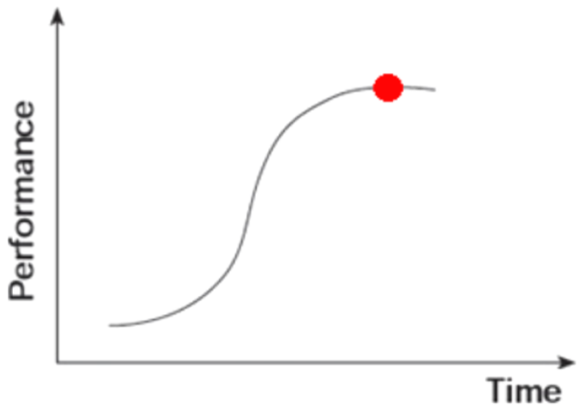

Figure 42. S-curve for electrostatic filters

By studying the S-curves for the three competitive techniques; electrostatic filters, fabric filters and centrifugal separation, it is possible to argue that the techniques are at different stages on the S-curve. Starting with the electrostatic filters, it is possible to argue that they most likely are present at the top of the S-curve, where the curve is starting to level out, see *Figure 42*. The reason behind the allocation is due to the maturity of the electrostatic technique. Electrostatic filters have, as discussed in the beginning of this thesis, been around for over a hundred years and the development for the last couple of decades has been scarce. Moreover has fabric filters already started to successfully capture market shares from electrostatic filters, which further provides evidence that the technique is in the end of the life cycle. By adding Rogers' adoption curve/innovation curve into the analysis it is also possible to argue that the electrostatic filter's market segment has shifted and contain mostly customers within the laggards and late majority group.

Fabric filters on the other hand still seems to be developing, even if it comprehends more of smaller incremental innovations such as choice of material rather the big radical or disruptive innovations. The development in combination with the gained market shares from electrostatic filters makes it possible to assume that fabric filters are moving along the S-curve at the moment, see *Figure 43*. Although, given the age of the technique as well as its incapability to develop any major novelties or radical innovations during the last couple of years it is also possible to argue that the technique is positioned closer to the top of the S-curve than the bottom. However, as the technique still is developing and it captures market shares, its customer group is very likely to be somewhere between the early majority and late majority.

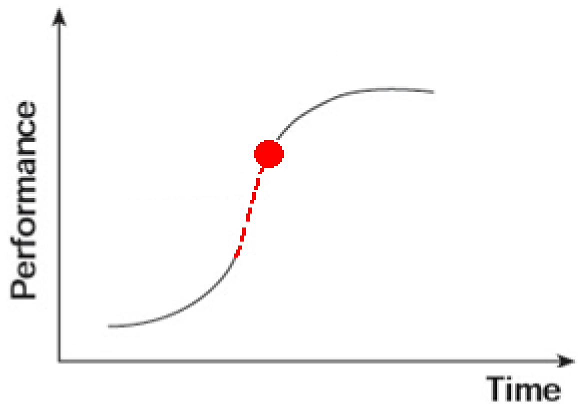

Figure 43. S-curve for fabric filters

The centrifugal separation technique offers a whole new type of flue gas separation. In that sense, the technique can be considered to be a radical innovation in terms of flue gas cleaning. As all major and radical innovations, it is positioned at the very beginning of the S-curve, see *Figure 44*, which also illustrates that it has a future potential to develop before it reached its peak from a performance perspective. Being a new innovative technique does also affect the customer group. As a new technique is not as tested as an established technique, investments in new technology is always combined with some amount of risk for the customers. Therefore, the present customers for centrifugal separation is most likely to be the innovators and perhaps some early adopters, as these are the less risk-avert costumers. Although, with 3nine's Olga on the market and a long history of centrifugal separation within neighboring application areas, the chances of a smooth cross of the chasm and access to the early majority segment is considered high.

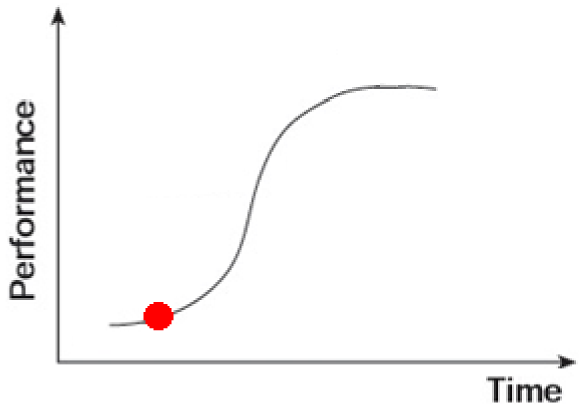

Figure 44. S-curve for centrifugal separators

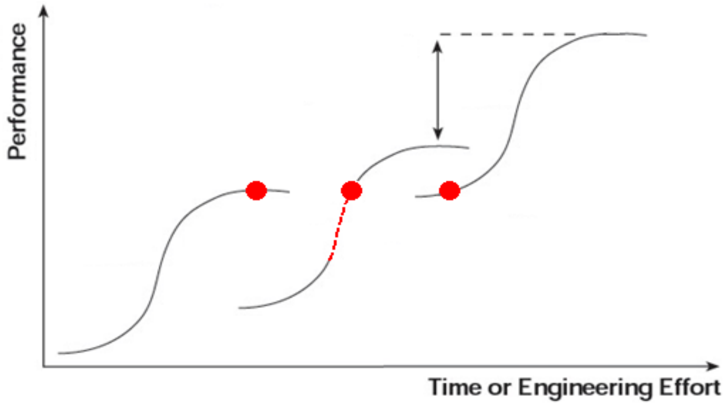

Figure 45. S-curves for electrostatic filters, fabric filters and centrifugal separators

Viewed together, all three techniques could be argued to have approximately the same performance today but with dissimilar historical development and different development possibilities. *Figure 45* below shows the historical development and recognizes the development potential as well as the performance gap between the technologies that could be reality in the near future.

Regarding the development potential of centrifugal separation, much can be done in order to maximize its separation capability for flue gas. Centrifugal separation has historically been used in order to separate fluid material, such as for an example milk, beer or ketchup. The separation of those products has also affected the design of a centrifugal separator which today has a disc stack that is round and with a very specific pattern. Both the size of the disc stack as well as the design and pattern of it could be developed in order to better suit separation of gases[56].

In terms of size, the disc stack's radius can be extended and thereby increase the separation area of the disc stack. The separation area is directly proportional with the separator's limitations in terms of volume; an increase in area would have large impacts on the separator's performance. As the radius and the area of a circle is related according to the equation: $A=\pi r^2$, where A is the area and r is the radius, even small changes of the radius provides large changes of the area and thereby also the maximum volume handled by the separator.

As mentioned, there is also a development potential regarding the design of the stack plates. At the moment, the centrifugal separator's stack plates are flat since sharp edges tend to create turbulence and mix the different phases within a fluid, which is the direct opposite to the purpose of a separator. That problem is however not present when it comes to separating gases as the phases of a gas is mixed in a whole other coalition. Therefore, the stack plates does not need to be flat in a centrifugal separator for gas or could be shaped in a zic-zac pattern, or any other pattern which is found suitable.[57]

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[56] Tommy Norén Manager Technologies Alfa Laval, personal interview on the 7th of May 2010.

[57] Tommy Norén Manager Technologies Alfa Laval, personal interview on the 6th of Feb. 2010.

6.3 Summary of Chapter 6

Chapter 6 aimed at answering the third and final research question; "*Are there any potential business opportunities for a combined system solution of heat recovery and particle separation of flue gas for Alfa Laval?*"

The chapter argues with basis from the resource based view that there is a large likelihood that centrifugal separation of flue gases would become adopted as a technique for mist elimination at power plants. The complexity of the technique is low, and thanks to 3nine's Olga as well as other neighboring application areas the trialability and observability is rather good given that it is a new innovation. From the power plants perspective the compability is also very good as mist elimination is considered a complementary process in relation to their core processes and could therefore be performed by Alfa Laval. However, the most important part in the analysis is emphasized in the technique's relative advantages. Centrifugal separation would in relation to existing techniques on the market demand only half the initial investment, a fifth of the required space and finally substantially less maintenance. These three major relative advantages do by themselves create a relevant business opportunity and sound business logic.

The chapter continues by examine if the business opportunity is big enough in order to become interesting for a company of Alfa Laval's size. With basis from the market estimation provided in the empirical chapter in combination with the costs for a typical solution using other techniques on the market, an estimation is provided that would give Alfa Laval a revenue of 600 million SEK annually, given that they capture one tenth of the market share and that their solution costs half of what their competitors solutions costs. 600 million SEK would for Alfa Laval correspond to half of their demanded increase in terms of invoices, which could be considered as promising since Alfa Laval conducted six acquisitions last year.

Last but not least, the chapter investigates the potential development possibilities for the centrifugal separation technique. According to the S-Curve, the technique is in its very beginning of what can be a promising development curve. This also means that the performance is likely to increase as the product matures and develops, which in turn makes the product more interesting compared to other competitive techniques. Furthermore, if the environmental legislations would tighten in the future the potential of the product in combination with several major relative advantages as well as offering a large market, makes centrifugal separation of flue gases a sound business opportunity for Alfa Laval.

7 EXPLORATION STRATEGY

When it comes to the exploration of potential business opportunities, companies often need to answer the question to either (1) develop the products or services internally or (2) acquire the resource and capabilities through an acquisition of another company. This chapter provides literature that can be used in order to make that sort of decisions as well an analysis regarding what would be to most suitable option for Alfa Laval.

7.1 Literature Review

The literature review regarding exploration strategies is divided in two parts. The first part investigates the make-or-buy decision, while the second part investigates how the acquiring organization shall deal with the acquired organization if the outcome of the make-or-buy decision ends up in an acquisition decision.

7.1.1 The decision to either make or buy

Regarding make-or-buy decisions, Christensen (1997) provides some aspects that need to be considered. According to Christensen (1997) large organizations have to think big, since they need both high margins and large markets. Christensen (1997) does also argue that it is essential for the company to create an organizational context in which the new technology or innovation have the possibility to prosper. Although, the rational resource allocation in a big established organization does consistently deny new innovations and technologies the resources they need to survive. Therefore, smaller organizations often have better conditions to manage new innovations compared to large organizations (Christensen, 1997).

If a manager shall address the challenge of bringing a new innovation to life, this can be made in two ways. The manager can either convince everyone in the big mainstream organization that the new technology will be highly profitable and therefore worth their attention, or address a smaller organization with a proper cost structure that would view the opportunity as a critical path to success. According the Christensen, the later alternative is far more tractable from a management and resource allocation perspective. (Christensen, 1997)

Moreover it is important that the organization has an open mind regarding failure, as the initial stab into the market presumably will not be successful in its first attempt. Therefore, an organization that brings up new innovations needs to be flexible in terms of failure as well as having the possibility to fail on a small scale in order not to destroy the brand or the company's credibility. Once again the obstacle could be handled in two different ways; either the large organization needs to change its value base and tolerance towards failure or a smaller organization with more open minded values need to be addressed. (Christensen, 1997)

Finally, for the personnel to remain motivated, it is important that the money spent on the project is limited. This in order to constantly try to find a way or solution, which for some set of customers, adds true value and thereby can make the project and organization cash-positive as fast as possible. This reasoning is furthermore backed up by Moore (1998) who argues that an effective way to cross the chasm is to target a narrow customer segment and solve their problem completely. The strong motivation among the personnel is moreover necessary in order to cope with the trials and errors inherent in cultivating a new market. (Christensen, 1997)

7.1.2 Integrate an acquired organization or keep it separated

In order to provide an assessment tool for the decision to either integrate or keep a company separated, Christensen (1997) has developed the so called Resources-Processes-Values framework (RPV-framwork), see *Figure 46*. The RPV-framework focus on three factors, namely; *resources*, *processes* and *values*. (Christensen, 1997)

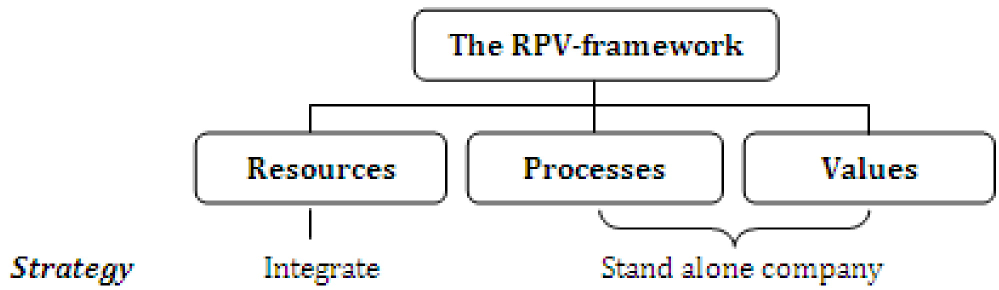

Figure 46. Christensen's (1997) RPV-framework

Among the three factors, resources are the most visible one. Resources include people, brands, equipment, technology, information, cash and relationships with suppliers, distributors and customers. Resources can furthermore be bought, sold, hired or fired which in turn makes them very flexible and movable. In that sense, resources is the factor that easiest can be transferred across the boundaries of organizations. Even though resources are the easiest factor to identify when evaluating if an organization successfully can implement a specific change, it does not provide a sufficient story in order to analyze an organizations capabilities. Even if two organizations would get identical sets of resources, the creation of these resources are likely to be very different, due to the fact that the capability to transform inputs into goods also is affected by the organization's processes and values as well. (Christensen, 1997)

Processes are patterns of interaction, communication, coordination and decision-making through which greater value is created as resources transform inputs into goods. Processes do however not only include manufacturing processes, but also product development, procurement, budgeting, planning, market research and employee development. Accept from differing in purpose, processes do also differ in visibility. Formal processes are often more visible compared to informal as they can be found in written documents and regulations. The informal processes do in the other way around evolve over time as they often are, and developed out of, habitual routines and ways of working. Despite formal and informal processes, there are also the cultural processes which mirror the culture of the organization. (Christensen, 1997)

The most crucial processes to examine as capabilities or disabilities are not the value-adding processes such as manufacturing, logistics, customer service or development. Instead it is the background processes and the enabling processes which is of interest and supports investment decision-making. How well does the organization respond to change; how is the market research normally performed; how is the planning and budgeting negotiated: how are those numbers delivered; are all critical processes. These are furthermore often the key processes to focus on in order to find out if a company's processes are a capability or disability. (Christensen, 1997)

The third and final class of factors that decides what a company can and cannot do regarding the make or buy decision is the company's values. A company's values are the criteria by which decisions and priorities are made. The values are therefore a form of standards by which employees make prioritizing-decisions such as if an order is attractive or unattractive; whether a customer is more important than another; whether an idea for a new product is interesting or mediocre et cetera. Prioritized-decisions are made by employees on every level within an organization. At the executive level these decisions are often about new products, services, processes or strategies, while it for example, among the sales-***people*** is more about day-to-day decisions regarding which customer to call or which products that is going to sell. (Christensen, 1997)

As the values affect to whole organization it is important that the company's true values are clearly communicated throughout the organization, at every level. This since strategic values will have a direct affect on the everyday decisions made within the organization. Christensen (1997) mentions one such example in terms of cost structures in the business model. Christensen further argues that if a company's over head costs demands the company to have a gross profit margin of 40%, it will be likely that middle managers will be encourage to kill ideas which promise gross profit margins below 40%. In other words, such a company would be incapable to successfully target a low-margin market. A market on which another company with other values, but the same set of resources and processes, might be successful on. (Christensen, 1997)

A second dimension regarding the values of a company are those that values a predictable change in relation to the size of the company and how big a business must be in order to remain interesting. As company's stock price represent a company's discounted present value of its projected earnings stream, many managers feel that they do not only need to maintain a certain growth but also maintain a constant rate of growth. This means that in order for a 100 billion SEK company to grow 10%, they need to find and exploit a new 10 billion SEK market the next year. In that sense, the size of a market opportunity which will solve a company's need of growth varies substantially. A market which excites a small company might not even be big enough to even be interesting for a big company. Christensen therefore argues that the bittersweet reward of success is that a company which becomes large enough loses its possibility to capitalize small emerging markets. The disability is not caused by a change in terms of resources, rather it is occurs due to changes in the company's values. (Christensen, 1997)

If the managers of a company find it to make competitive or financial sense to acquire another company rather than develop a product or service themselves, the RPV-framework can be a useful tool to frame the challenge of integrating the acquired organization. A central question for the managers is to ask themselves if the added value from acquiring the company is justified and comes from its resources, or if the substantial value is created by its processes and values. If the acquired company's processes and values stand for, the real drivers for its success, it will be a bad idea to integrate the company into the acquiring organization and thereby risk strangling that success. Integration will vaporize the processes and values of the acquired company as it will need to adopt its way of doing business according to the acquiring company's manners. In those cases it is often better to let the company stand alone, and let the acquiring company infuse its resources into the acquired company's processes and values. In that sense, the acquiring company can truly make the most of the newly acquired capabilities. If the added value of an acquisition on the other hand is captured in the acquired company's resources, the acquired company can with advantage be integrated into the acquiring company. By integrating the acquired company's personnel, products and customers into the acquiring organization it will be possible to leverage on the acquiring company's existing capabilities. (Christensen, 1997)

7.1.3 Risks Associated with Acquisitions

Risks are an inherent characteristic of all forms of strategic decision due to the uncertainty regarding the outcome and result of the decision made. Acquisitions have been especially targeted by many executives as one of the most important strategic decision due to their considerable resource and performance implications for the companies (Wally & Baum, 1994). Acquisitions are further distinguished from other strategic decision because of their risk characteristics in terms of visibility and tendency to create intense personal commitment (Pablo, Sitkin, & Jemison, 1996).

Pablo, Sitkin & Jemison (1996) further argues that the higher the organizational fit is between the acquiring organization and the acquired organization, the less risky the acquisition of the candidate will be. The organizational fit does is in turn focused at culturally-defined procedural routines, behavior norms, and to what degree these characteristics differs between the two organizations. Therefore a distinction between strategic fit and organizational fit needs to be made in terms of risk management of acquisitions (Pablo, Sitkin, & Jemison, 1996). Strategic fit could be defined as an opportunity ceiling while the organizational fit is defined as a threat floor, see *Figure 47*.

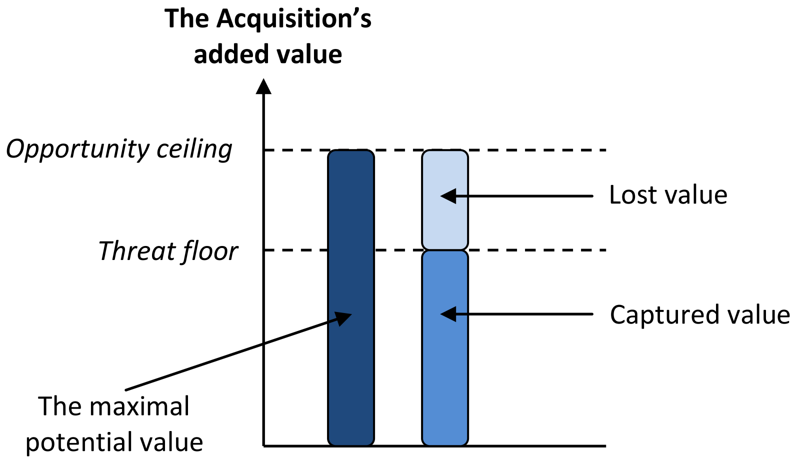

Figure 47. An illustration of the potential added value of an acquisition (developed by the authors).

As shown in *Figure 47* the strategic fit provides the boundaries in terms of possible value creation while the organizational fit determine how much of the creation that can be captured. In cases where the strategic fit is regarded as highly profitable, the organizational fit might be counterproductive between the two organizations causing undesirable outcomes such as conflicts or disruption. The potential added value created by an acquisition therefore depends on how successful the capability transfer is among the two companies. The capability transfer is in turn deeply affected by potential organizational conflicts, which thereby have direct fatal consequences for the acquisition's value creation (Pablo, Sitkin, & Jemison, 1996). Pablo, Sitkin & Jemison (1996) do also state that sufficient resource requirements are crucial in order for an acquisition to be successful. Not only resource requirements for the price paid to complete the acquisition transaction itself, but also for future financial and human resource requirements which are needed to exploit the potential benefits of the acquisition.

Moreover, based on studies from six different experiments with over 580 participants, Lopes (Lopes, 1984) argues that risk-seeking decision-makers weight information regarding opportunities heavier compared to information related to threats. Risk-averse decision-makers on the other hand, that concentrates at minimizing the risks of unfamiliar strategic decisions, focus more on shared structural cultures, norms and inertia within the companies which are threats associated with the organizational fit. However, in order for an acquisition to become successful and maximize the potential value creation, both the strategic fit and the organizational fit with their associated risks needs evaluated prior a potential acquisition according to Pablo, Sitkin & Jemison (1996).

7.2 Analysis of how to explore the business opportunity

In order to explore the possible business opportunity Alfa Laval holds two viable options. One is to further develop Pure Vent and the other is to acquire the resources and capabilities from their competitor 3nine. To explore these opportunities Christensen's models is used in order to decide what would be the most suitable option for Alfa Laval.

7.2.1 Develop Pure Vent or acquire 3nines technology

One major issue for Alfa Laval, if they would chose to develop the Pure Vent into a product for mist elimination of flue gases, is the resource allocation within the organization. According to Norén[58], there is a struggle to get the required resources released from the line organization within Alfa Laval. The success with the earlier mentioned ART-project could be considered an exemption rather than the normal case. The focus of Alfa Laval has therefore been to target and acquire other companies rather than to innovate and develop new technology themselves. A notion made of Alfa Laval's R&D department, from the time spent at the company during this thesis, is that it focuses more on releasing small incremental innovations for the already established technologies within the organization than searching for new, radical ones.

Another major issue for Alfa Laval is the need to find markets that are large enough instead of focusing on developing products that add value for the customers. Searching for new large markets is not a bad thing in itself, but it shift focus from other processes and make it harder to enter a new market. As argued by Moore (1998) it is easier to enter a new market and cross the chasm if a small market segment is targeted, and that process would probably be easier for a company that not only takes interest in vast markets.

With the same rationale, it would be more likely for a small flexible company than for Alfa Laval to deal with the initial failures discussed by Christensen (1997). If Alfa Laval should be able to adjust and cope with such failures, they would need to radically change their organizational values. For a company with almost 130 years of history, changing the values of the organization would face much more inertia and be a larger obstacle compared to the alternative to acquire the technology.

Given Alfa Laval's difficulties regarding allocation of resources, their demand for vast markets and their organizational values when it comes to failures in combination with their strong history of acquiring companies, the most suitable option for Alfa Laval is to acquire 3nine's technology rather than to develop it internally.

Although, if Alfa Laval would acquire 3nine's technology further analysis is needed in order to determine if the company should be integrated into Alfa Laval or stand on its

[58] Tommy Norén Manager Technologies Alfa Laval, personal interview on the 7th of May 2010.

own as an separate organization. Therefore, in accordance with Christensen's (1997) RPV-framework, a closer examination of Alfa Laval's resources, processes and values is required.

7.2.2 Integrate or separate 3nine's technology

Alfa Laval's resources in combination to the business opportunity where described in chapter 5 and is only given a short summary here. To sum it up, Alfa Laval possesses valuable resources in form of established sales channels all over the world with close connection into the Energy & Environment market segment. The sales channels are experienced in performing direct sales as well as adopting to new technologies given Alfa Laval's history of diversification. Furthermore is Alfa Laval's brand one of the company's key resources and given its strong history the customers are convinced that Alfa Laval will remain a permanent player.

Alfa Laval is the global leader in centrifugal separation and therefore possesses specialized skills and knowhow within the field. They also possess patents for the Pure Vent technology, which can be leveraged on if the technology is further developed. Last but not least, the company also has a key resource in its strong financial strength.

Regarding their processes, Alfa Laval has well developed customer services, manufacturing processes as well as established distribution and development centers. However, according to Christensen (1997) these value adding processes are not the most crucial processes to examine. Instead it is the background and enabling processes that needs to be focused at. For Alfa Laval the growth has mainly been conducted through acquisitions during the recent years. Only during 2009, six acquisitions were carried out which has given the company experience in integrating new technology into the organization. Therefore the *Not Invented Here* syndrome, that describes persistent corporate cultures that avoid using or buying already existing products or knowledge because of their external origin, would not be a concern for Alfa Laval. The process within which Alfa Laval takes innovative ideas to the market contains both external sources such as universities and internal ones such as employee's ideas. The critical part of this process is however when the general managers make the go or no go decision. This decision is among other things based on the fit with Alfa Laval's business strategy.

Concerning Alfa Laval's values the company demands a 15% operating margin (Alfa Laval, 2010), which implies that business opportunities with lower potential are rejected. Alfa Laval's other goal is to have an invoicing growth of at least 5% over a business cycle. Given Alfa Laval's turnover of 26 billion SEK in 2009 a growth of approximately 1.3 billion SEK is demanded for 2010. Thus small markets are often not considered in favor of larger ones in order to solve the company's need of growth.

By studying Alfa Laval based on the RPV-framework it is possible to claim that an acquisition of 3nine would have the purpose of adding value through acquiring the resources or more precisely a developed product. The process of developing the product internally is then passed out and in that way Alfa Laval's time to market is shortened. Furthermore, there is no risk of failing to develop the technology internally as the new knowledge is acquired as well.

Moreover, by acquiring 3nine the issue of new products being strangled by Alfa Laval's processes and values is avoided. Except from avoiding these issues, the technology can take advantage of the synergies of Alfa Laval organization, such as established sales channels, distribution networks, financial backing and a way past the high entry barriers of the market. Alfa Laval's processes and values are not optimized to foster new innovations, but are highly effective when it comes to exploiting the business opportunity they provide when the technology already is in place. Having the possibility to acquire the resources and then adapting them into Alfa Laval's processes and values would potentially combine the better of two worlds.

If the main purpose of an acquisition is to access and acquire a new set of resources, the acquired company can with advantage be integrated into the acquiring organization according to Christensen (1997). As discussed above, such integration of the personnel, products and customers will make it possible to leverage on Alfa Laval's capabilities and create synergies between the two companies. Given this rationale further investigation regarding an acquisition of 3nine's technology is recommended for Alfa Laval, with the option to develop the technology internally. Even though 3nine should be an integrated part of Alfa Laval, it would be favorable to create a new unit within the organization for centrifugal separation of flue gases as the characteristics and technology somewhat differs from Alfa Laval's other technologies.

7.2.3 Risks associated with acquiring 3nine

As stated in the literature review, there are primarily two sorts fits that needs to be in place for an acquisition to become successful, namely; the strategic fit and the organizational fit (Pablo, Sitkin, & Jemison, 1996). In terms of strategic fit, Alfa Laval has a strong history of conducting acquisitions of smaller companies and an outspoken strategy to grow through acquisitions as well as internal development. Moreover are 3nine's resources and capabilities closely related to centrifugal separation which is one of Alfa Laval's key technologies. The strategic fit can therefore be argued to be high between the two companies.

The risks associated with the organizational fit are on the other hand important to investigate further. According to Pablo, Sitkin & Jemison (1996), risks associated with the organizational fit includes culturally-defined procedural routines, behavior norms, organizational culture, inertia in terms of change et cetera. All of these factors can be considered a risk due to the fact that they can contribute to conflicts or disruption and thereby heavily affect the value creation of an acquisition.

Starting with procedural routines, Alfa Laval has a well defined organizational structure as well as R&D routines. 3nine on the other hand is a small, fast moving, innovative company in the entrepreneurial phase with few employees. Having a well defined structured organization has not yet been necessary for 3nine and it could possibly be an issue when fitting 3nine into Alfa Laval. However, since 3nine's Olga already is a complete product it would not need to go through Alfa Laval's innovation process and its associated routines, which decrease the complexity of the integration. Moreover has Alfa Laval a lot of earlier experience regarding integrating small entrepreneurial companies into its organization. Alfa Laval's earlier experience will also affect and decrease the potential complications related to the integration.

Regarding the behavior norms and organizational culture, these could also be regarded as different between the two organizations. Alfa Laval with its line-based organization has established norms in terms of values, beliefs, attitudes, formal and informal leaders and so on. 3nine does also reasonably have established norms, but due to the fact that it is 3nine that is the target for the acquisition as well as being the smaller company, they will need to adjust. This means that some of the cross-functional and creative ways of working that is typical in a small entrepreneurial company such as 3nine might be strangled by the norms and ways of working within Alfa Laval. The potential conflict regarding the two organizations' norms is a risk which Alfa Laval needs to be aware of and cope with. However, once again the earlier experience of integrating acquired companies might become handy and of great importance for a successful integration.

The inertia against change is as mentioned another factor which could create conflicts or disruption, especially within Alfa Laval. Alfa Laval has from a historical point of view primarily focused on centrifugal separation of fluids and not gases. The extension to also include centrifugal separation of gas is likely to encounter inertia within Alfa Laval's organization as it will require both time and resources. The same time and resources which otherwise could have been allocated to development of the established centrifugal separators for fluids. There is therefore a risk that the technique for centrifugal separation of gases will have difficulties to receive the necessary allocation of time and resources that it needs to successfully leverage on Alfa Laval's capabilities. The risk is however lowered due to the fact that the technique is acquired and not developed internally. As the technique for centrifugal separation of gases is acquired, it automatically gains the management attention it needs and the sufficient amount of resources can be allocated. Alfa Laval does however once again be aware of the risks associated with the inertia within the organization.

From an overall perspective it is possible to argue that the organizational fit, just as the strategic fit, is high. There are some factors such as procedural routines, behavior norms, organizational culture and inertia that could constitute a risk, but given Alfa Laval's positive track record and earlier experience regarding acquiring and integrating other companies, they could all be considered as rather small. As the risks of the acquisition are small both in terms of strategic fit as well as organizational fit, the potential added value from the acquisition of 3nine have the prerequisites to become large.

7.3 Summary of Chapter 7

Chapter 7 aimed at answering the question of how to explore the business opportunity given in chapter 6. The answer to that question was separated into two parts. The first part concerned the make-or-buy decision and the second part concerned if the acquired company should be integrated into Alfa Laval or remained as a standalone company.

Given Alfa Laval's difficulties regarding allocation of resources, their demand for vast markets and the inertia within the organizational due to its values, acquiring the technology from 3nine was considered a better option than developing it internally.

An analysis based on Christensen's RPV-framework showed that the acquiring of 3nine and their technology had the main purpose of adding new resources to Alfa Laval rather than processes or values. Therefore, the recommended action is to implement 3nine and their technology into Alfa Laval's organization in order to gain synergies. However, since the centrifugal separation of flue gases is somewhat different from centrifugal separation of for instance milk, an additional unit for the technology and the market should be considered.

8 DISCUSSION

This thesis has both investigated and evaluated potential business opportunities for Alfa Laval within the market of flue gas treatment. However, due to the delimitations in terms of both scope and time, some interesting aspects could have been pinpointed or developed further. The discussion chapter of this thesis aims at bringing light on topics which would have been interesting to develop further, but has fallen outside the scope.

First of all, the thesis states that the present environmental legislations for particles within flue gas are 50mg/Nm3 for new plants and 100mg/Nm3 for existing plants. It also states that the environmental legislations are country specific with exception from collaborating unions such as the EU, where the union's legislations are superior the individual country's legislation. However, it would have been interesting to further investigate and elaborate on how tighter environmental legislation would affect the market for mist elimination.

At the moment, the environmental legislations do only focus on the volume of particles and not the size of the particles. The focus on volume has in turn provided the power plants with an easy way out in terms of mist elimination. Capturing large particles is easier and contributes more to the total volume compared to capturing small particles. Although, it is the small particles with a diameter smaller than 2.5 μm, often referred to as 2.5 particles, which is the true health hazard. As humans or animal breathes, 2.5 particles are small enough to find their way into the airways and down to the lungs, which is very dangerous.

Therefore, as the decision makers within for an example the EU-Commission starts to recognize the problem with the current focus on volume, there are reasons to believe that a shift of focus will become reality in a not too distant future. As capturing small particles is considerably harder than large particles; cyclones, wet scrubbers and other low-tech mist elimination techniques will need to be exchanged against for instance centrifugal separators. This since a cyclone cannot capture particles smaller than 5 μm while the centrifugal separator can capture particles as small as 0.3 μm.

Another interesting aspect to pinpoint is the market and the market estimation provided in this thesis. The thesis focuses on the existing market as existing power plants are more likely to invest in retro fit kits for flue gas treatment. It would however also be interesting to further analyze new plants and the potential growth of the market. The human population is constantly growing, and so is the demand for electricity. The rough market estimation provided in this thesis does however only study and analyze the present population of boilers and not future ones. Given the trends provided in the empirical chapter which shows that there will be upcoming investments in for instance coal power plants, it is possible to argue that the market for flue gas treatment is essentially larger than the 600 MSEK stated in the market estimation. Especially if the new build power plants and the increasing trends are included.

From a methodology perspective it is also important to pinpoint that not all competitors have been taken into consideration within the scope of this thesis. There are a vast amount of companies that offers for instance heat exchangers or separators. In order to cope with the vast amount, the snowball sampling approach was utilized in order to identify the key players within each technology segment. Based on qualitative interviews with leading actors within each segment, key competitors and important up-coming competitors could be identified and further investigated. The competitors on each market could of course be investigated further in a deeper manner using for instance the resource based view. The process would however not fit within the time span provided for this master thesis and is therefore positioned out of scope.

With the same rational as above, the perhaps most interesting and important competitor; 3nine, would have been beneficial to investigate deeper. Although as 3nine are considered highly interesting, Alfa Laval has specifically requested that further contact with 3nine is performed by them rather than by the work of this thesis. However, since it is people who takes the decision and not only figures or numbers on a paper, it would have been interesting to investigate 3nine's ambitions in term of strategy, exit for their investors and future plans.

Despite the competitor, this thesis has also investigated and interviewed potential buyers. Although, due to travel distances and the ability to come in contact with managers high enough in the corporate structure, the interviews has only been performed with Swedish actors such as Fortum and Vattenfall. The validity of the data collected could be improved by including potential buyers from other countries, both within and outside of the European Union. This since the Swedish electricity market, as discussed in earlier chapters, is considered a niche market.

A final aspect which could have been developed further is the segmentation of the different combustion fuel types. The different combustion fuels have different combustion characteristics and thereby provide slightly different flue gases, both in terms of volume but also emissions. Even if the focus is directed at one specific type of fuel, as for instance coal, it might have different characteristics depending on its composition and origin. Coal from for instance Poland, the US and India has very different compositions which in turn affect the amount of ashes that is produced during the combustion. By performing a deeper investigation regarding the different combustion fuels it might be possible to identify fuels which are extra suitable for centrifugal separation. Identifying such fuels would provide useful and important input data for the market penetration strategy.

9 CONCLUSION

The purpose of this master thesis was to investigate potential business opportunities for Alfa Laval in terms of heat recovery and mist elimination of flue gases from boilers. In order to fulfill the purpose, four research questions were formulated which jointly answers the purpose. The answers to the four research questions are provided below.

What does the market characteristics look like in terms of competition, technical solutions and legislations?

In order to answer the first research question the heat recovery and mist elimination parts of the market needs to be separated. At the moment, the heat recovering part of the market is only available through condensation at power plant combusting bio-fuels. This due to the fact that the fuel needs a certain amount of latent energy in form of moisture in order for heat recovery to be profitable. Other fuels than bio-fuels do not contain the required amount of latent energy and does moreover create problems due to their creation of sulfur-acid.

Mist elimination on the other hand is required on all types of fuels that produce hazardous emissions due to environmental legislations. The present legislations on particles tolerate 50-100 mg/Nm^3, depending on if it is an existing or a new plant. The major market shares in terms of mist elimination are currently hold by electrostatic filters and fabric filters, which both are old and mature techniques that has been around for a long time. Due to the maturity of the techniques, the competition is rather tough as there are both many players on the market as well as large players such as Alstom and Siemens. However, even if the competition is tough, the market is considered attractive since the supplier power, threats from supplements and threats from new entrants are considered low.

What internal resources and capabilities does Alfa Laval possess that could be used or developed in a potential system solution for flue gas treatment?

As the result of being a large multinational organization, Alfa Laval possesses many resources and capabilities a small organization does not. On an organizational level Alfa Laval has global established networks and sales channels as well as a strong brand. The company is moreover strong in terms of human, technological and innovative resources as well as financial strength.

Alfa Laval's core competences are their know-how within heat transfer, separation and fluid handling. Especially separation and fluid handling are closely related to mist elimination of flue gases and could be leverage upon. Within Alfa Laval's product portfolio there are several products that could been used in a potential system solution for flue gas treatment. However, the strongest shining star is Pure Vent. Pure Vent is a centrifugal separator designed to remove oil and particles from crankcase gases on marine diesel engines. According to Alfa Laval's engineers it would be possible, without any major obstacles, to redesign Pure Vent for flue gases from power plants.

Are there any potential business opportunities for a combined system solution of heat recovery and particle separation of flue gas for Alfa Laval?

A potential business opportunity for Alfa Laval would require both a large profitable market as well as a product with clear relative advantages. The centrifugal separation technique which is used in both Alfa Laval's Pure Vent and 3nine's Olga would become a challenging substitute to the established filtration solutions on the market today.

According to Roger's (1995) five forces, the centrifugal separation technique has a good potential of getting adopted. Moreover it would add true value for its customers. Centrifugal separation of flue gases would in comparison to the existing filtration techniques require half the investment costs, a fifth of the required footprint and a major decrease in maintenance cost since no bags or filters would need to be exchanged.

Furthermore, a rough market estimation which is based on statistics from CIA as well as the European Commission estimates that the market for mist elimination is worth about 6 billion SEK in 2007. Since the relative advantages of centrifugal separation are vast, Alfa Laval would face a 600 million SEK market annually if they are able to capture 10% of the market. 600 million SEK is equivalent to about 50% of Alfa Laval's targeted invoice increase for 2010, which in turn makes it a sound business opportunity for the company.

Given that there is a business opportunity, how should Alfa Laval strategically exploit such an opportunity?

Alfa Laval could either chose to develop the Pure Vent internally or chose to acquire 3nine and thereby overcome the finalized product Olga. According to Christensen (1997) large organizations are often favored by acquiring instead of developing as they have difficulties in allocating resources, require vast markets and have organizational values that oppose the innovative development process. By using Christensen's framework, an analysis was performed showing that Alfa Laval was no exception. The most strategically correct option for Alfa Laval would therefore be to acquire 3nine.

The decision to acquire 3nine raised the question if 3nine should be implemented into Alfa Laval's organization or be left as a separated standalone company. Based on an analysis using Christensen's RPV-framework, the strategically correct option in this case was to integrate 3nine into Alfa Laval's organization. This since the major purpose of the acquisition was to get hold of 3nine's resources and not their processes or values. Furthermore, by integrating 3nine synergies could be achieved in advantages for the centrifugal separation technique.

10 RECOMMENDATIONS

Based on the analysis and findings of this master thesis following recommendations for actions are provided for Alfa Laval:

- Enter the mist elimination market with centrifugal separation technology
  - This should be done through acquiring 3nine's technology if considered possible by Alfa Laval's M&A department.
  - If 3nine's technology is acquired, integrate its resources and leverage on Alfa Laval's established resources and capabilities.
- If an acquisition of 3nine is not possible, develop and redesign Pure Vent for mist elimination of flue gases.
- Target boilers with an effect of 0-30 MW as these constitute 85% of the market and the required large volumes can thereby be achieved.
- Create a competitive advantages based on the cost structure and the size of the centrifugal separation technique rather than its technical performance.

10.1 Suggestions for further investigation

In order for this master thesis to investigate if the business opportunity was attractive enough for Alfa Laval, a rough market estimation was performed. As the master thesis covers a much larger context than just the market estimation, some general assumptions was required. However, in order to create a more specific and accurate market estimation, this master thesis suggests that a study is performed with the single purpose to create a solid market estimation of the mist elimination of flue gas market.

Moreover would the full potential of the Pure Vent need a deeper investigation. Engineers at Alfa Laval have stated that the product could be redesign in order to fit the mist elimination of flue gas market. Although, at the moment Pure Vent can only handle gas volumes up to 150 m^3/h which is to small with a factor 100 in order to manage a 3 MW power plant or with a factor 1,000 for a 30 MW. The Pure Vent could however be redesigned in order to become larger in two directions; both in terms of height but also in terms of radius. What the cost structure for a Pure Vent would look like after such redesigns would for this thesis only become highly speculative given the vast amount of uncertain parameters. Therefore, further investigations need to be performed in order to find out both the maximal potential of the Pure Vent, but also what the cost structure would look like.

A final suggestion for further investigation would be to make a deeper analysis of 3nine and their technology. That sort of analysis is required if an acquisition of 3nine would become reality. Such an analysis is furthermore needed in order to establish what 3nine might be worth and what a proper price tag for the company would be. The task of performing such an analysis would preferable falls under Alfa Laval's M&A department as they possess the relevant knowledge and skills.

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12 APPENDENCES

In this final part of the report statistics, figures and other relevant information will be gathers which is of importance for either the report or Alfa Laval.

Appendix I – Market estimation

Accordingly to Hutt & Spech (2007) market estimates give companies with vital information that provides guidelines for the general direction the firm will take in terms of markets and product opportunities. They also complement the sales forecasts and are therefore necessary for budget allocations to those opportunities. Therefore a market estimate is given here based on findings from the Swedish market and world statistics.

In chapter 3.7 an estimation of the market size of boilers between 0-30 MW in 2007 where performed followed by a sensitivity analysis of the market. The sensitivity analysis where made to mitigate the risk of assuming that the distributions of the boilers are the same in Sweden as in the world and the EU27. The outcome was three scenarios, one so called worst-case, one estimated and one so called best case estimate. *Table 3* below shows these scenarios for EU27 and for the whole world, including EU27, where the worst case estimates the number of boilers to be 70% of the total number, the estimated case uses 85% and the best case 90%.

Table 3. Number of boilers

		Worst-case	Estimated-case	Best-case
EU27	units	16,000	19,500	20,000
World	units	90,000	110,000	115,000

These are the installed base of boilers which the most part of already has mist elimination installed. However many of these are very old and the mist installation needs to be replaced sooner or later. The reason may be that the legislative demands are higher and the old equipment cannot reach the new demands, the maintenance cost has reached such a high level that it is better to replace the equipment or the environment impact needs to be reduced to cope with the owners environmental policy. Accordingly to Wieslander[59] Alstom's Fabric Filters filter bags are replaced after approximately 5 years, however not the whole installation is not replaced so often. Instead an assumption of replacing the installation every 30 to 40 year is better. On the safe side 40 years are used to calculate the average yearly market. In *Table 4* below is estimated market shown based on a replacement need every 40 years.

[59] Peter Wieslander Technology Manager - FF process Alstom, personal interview on the 20th of April 2010.

Table 4. Demand each year

		Worst-case	Estimated-case	Best-case
EU27	units/year	400	488	500
World	units/year	2,300	2,800	2,900

To get a market size the unit price is needed. This number varies accordingly to volume of gas and how much particles the gas contains. The installation costs for fabric filters are about 40% lower than for electrostatic filters[59] however exact figures are hard to obtain because the variation is large between cases. Karlsson[60] argues that an approximate value for electrostatic filters and fabric filters installations are between 5 and 10 million SEK on boilers that have an effect lower than 30 MW. In chapter 6.2.1 the price of a centrifugal separation were argued to be approximately half of the price for a filter solution, based on information from 3nine. If the lower value of the installation cost, 5 million SEK, are used and divided by two an assumption of 2.5 million per boiler is retrieved. This number is used to estimate the total market size of mist elimination of boilers between 0-30 MW in *Table 5*.

Table 5. Market size

		Worst-case	Estimated-case	Best-case
EU27	MSEK	1,000	1,200	1,300
World	MSEK	5,600	6,900	7,200

From *Table 5* above it is estimated in the worst case scenario that the whole market size is 5,500 million SEK. The question is then of how much of this size Alfa Laval can capture given the business opportunity. Three possible market shares are used for this final calculation, namely 5, 10 and 20% market share creating nine different scenarios in the EU27 and the world market, see *Table 6*. These market shares are assumptions based on the present market, Alfa Laval's resources and capabilities as well as that the technical specifications of the new product is reached.

Table 6. Market share

		Worst-case	Estimated-case	Best-case
EU27	5%	50	60	65
World	5%	300	350	360
EU27	10%	100	120	130
World	10%	560	690	720
EU27	20%	200	245	250
World	20%	1,130	1,380	1,440

[60] Peter Wieslander Technology Manager - FF process Alstom, personal interview on the 20th of April 2010.

Appendix II – Conducted Interviews

Internal	Name	Title	Date	Duration	Type
Alfa Laval	Lars Jereaus	Market Unit Manager - Power	6-Jan and 19-Mar	1h + 1h	Personal
Alfa Laval	Rolf Christensen	Business Development Manager	7-Jan and 18-Mar	1h + 2h	Personal
Alfa Laval	Staffan Königsson	Process Analyst and Design	9-Feb and 26-Mar	1h + 1h	Personal
Alfa Laval	Lena Sundqvist	Market Unit Manager - Marine & Diesel	9-Feb	1h	Personal
Alfa Laval	Göran Ström	Technology Manager - Separator Systems	16-Jan	0.5h	Personal
Alfa Laval	Tom Manelius	Manager Process Analyst & Design	17-Jan and 25-Mar	1h + 1h	Personal
Alfa Laval	Bo Karlsson	Market Unit Manager - High Speed Separators	25-Mar	1.5h	Personal
Alfa Laval	Tommy Norén	Manager Technologies	Continuously	-	Personal
Alfa Laval	Jaroslav Halac	Manager - Mergers & Acquisitions	17-Mar and 7-May	1h	Personal
Alfa Laval	Steen Rosenbom	Business Development Manager	23-Apr	0.5h	Telephone

External	Name	Title	Date	Duration	Type
Radscan	Helena Roos	Process Engineer	17-Feb	1h	Personal
Radscan	Tomas Börjesson	CEO	17-Feb	2h	Personal
Götaverken Miljö AB	Ulf Hägg	Manager - Process Design	23-Feb	1.5h	Personal
Svensk Rökgasenergi AB	Martin Östlind	Sales manager - Nordic Countries	10-Feb	1.5h	Personal
Svensk Rökgasenergi AB	Lennart Granstrand	Founder and Development Manager	10-Feb	0.5h	Personal
Stål & Rörkonstruktioner AB	Göran Carlsson	Owner and CEO	4-Feb	1.5h	Personal
Gupex	Janne Magnusson	Project Manager	14-Mar	2h	Personal
Fortum	Joakim Mellström	Technology Manager	26-Mar	1.5h	Personal
Alstom	Peter Wieslander	Technology Manager - FF process	20-Apr	1h	Personal
Alstom	Per Johansson	Technology Manager - ESP Mechanical	20-Apr	1h	Personal
Alstom	Stefan Åhman	Technology Manager - Dry gas absorption	20-Apr	1h	Personal
Alstom	Mikael Larsson	Manager - Technology Managers	20-Apr	1h	Personal
Borås Energi	Pauline Lindberg	Coordinator - Energy and Environment	21-Apr	0.5h	Personal
Svensk Fjärrvärme	Sonya Trad	Statistics & Analysis	26-Mar	0.5h	Telephone
Naturvårdsverket	Björn Ejner	Administrator - Incinerators	23-Apr	0.5h	Telephone

Appendix III – Electricity Production Capacity within the EU27

Electricity Production Capacity
2007 (in MW)

	Total	Conventional Thermal	Nuclear	Wind	Geothermal	Hydro	of which: pumping
EU27	779 192	449 129	132 829	56 270	698	140 266	38 306
Share	100.0%	57.6%	17.0%	7.2%	0.1%	18.0%	27.3%
EU26	749 289	431 769	129 526	56 237	698	131 059	37 442
Share	100.0%	57.6%	17.3%	7.5%	0.1%	17.5%	28.6%
BE	16 360	8 842	5 825	276		1 417	1 307
BG	9 700	4 902	1 892	30		2 876	864
CZ	17 558	11 508	3 760	114		2 176	1 147
DK	12 608	9 475		3 124		9	
DE	128 780	77 738	20 208	22 247		8 587	5 223
EE	2 760	2 697		58		5	
IE	7 287	5 905		855		527	292
EL	13 677	9 681		846		3 150	699
ES	88 246	47 412	7 365	15 097		18 372	5 347
FR	116 284	25 672	63 260	2 220		25 132	4 303
IT	93 198	68 708		2 702	671	21 117	7 544
CY	1 139	1 139					
LV	2 131	569		26		1 536	
LT	4 588	2 483	1 183	47		875	760
LU	1 638	463		35		1 140	1 100
HU	8 542	6 607	1 825	61		49	
MT	571	571					
NL	23 677	21 382	510	1 748		37	
AT	19 429	6 441		977	2	12 009	3 580
PL	32 497	29 863		306		2 328	1 406
PT	14 970	7 692		2 201	25	5 052	1 029
RO	20 203	12 458	1 411	3		6 331	
SI	3 035	1 351	666			1 018	
SK	7 324	2 609	2 200			2 515	916
FI	16 698	10 815	2 671	110		3 102	
SE	34 294	7 873	9 074	710		16 637	45
UK	81 998	64 273	10 979	2 477		4 269	2 744
HR	3 906	1 814		17		2 075	293
MK							
TR	40 835	27 271		146	23	13 395	
IS							
NO							
CH	19 184	851	3 220	12		15 101	1 636

Source: Eurostat, May 2009

Appendix IV – Gross electricity generation within the EU27

Gross Electricity Generation
2007 (in TWh)

	Total	Conventional Thermal:	- Coal	- Oil	- Gas	- Other Power Stations	Nuclear	Pumped Storage	Renewables *
EU27	3 362	1 867	988	112	760	6	935	34	526
Share	100.0%		29.4%	3.3%	22.6%	0.2%	27.8%	1.0%	15.6%
EU26	3 257	1 804	941	111	746	6	913	33	507
Share	100.0%		28.9%	3.4%	22.9%	0.2%	28.0%	1.0%	15.6%
BE	88.8	35.3	6.5	0.8	27.2	0.8	48.2	1.3	4.0
BG	43.3	25.4	22.4	0.6	2.4	0.0	14.6	0.4	2.9
CZ	88.2	58.2	53.8	0.1	4.3		26.2	0.4	3.4
DK	39.2	28.1	19.9	1.1	6.9	0.2			11.1
DE	637.1	395.2	299.8	11.3	84.1	0.1	140.5	7.6	93.8
EE	12.2	12.0	11.4	0.0	0.6				0.1
IE	28.2	25.1	7.7	2.0	15.5	0.0		0.3	2.8
EL	63.5	58.1	34.7	9.6	13.8	0.0		0.8	4.6
ES	303.3	185.7	73.1	18.5	93.8	0.3	55.1	3.0	59.4
FR	569.8	56.3	24.4	6.2	25.7		439.7	5.5	68.3
IT	313.9	259.0	44.1	35.4	178.3	1.2		5.7	49.2
CY	4.9	4.9		4.9					0.0
LV	4.8	1.9	0.0	0.0	1.9				2.8
LT	14.0	3.1	0.0	0.4	2.4	0.2	9.8	0.5	0.6
LU	4.0	2.9			2.9			0.8	0.3
HU	40.0	23.3	7.4	0.5	15.3	0.0	14.7		2.0
MT	2.3	2.3		2.3					
NL	103.2	89.9	24.9	2.2	62.6	0.2	4.2		9.1
AT	63.4	19.1	6.3	1.3	11.2	0.3		2.5	41.9
PL	159.3	153.3	145.6	2.3	5.1	0.3		0.6	5.4
PT	47.3	30.4	12.4	4.9	13.1	0.0		0.4	16.5
RO	61.7	38.0	25.1	1.1	11.8		7.7		16.0
SI	15.0	6.0	5.5	0.0	0.5	0.0	5.7		3.4
SK	28.1	7.6	4.8	0.7	2.0	0.1	15.3	0.2	5.0
FI	81.2	33.4	21.4	0.5	11.1	0.4	23.4		24.4
SE	148.8	3.7	0.7	1.1	1.5	0.5	67.0	0.0	78.2
UK	396.1	308.9	136.7	4.7	166.1	1.4	63.0	3.9	20.4
HR	12.2	7.8	2.4	2.3	3.1	0.0		0.2	4.3
MK		0.0							
TR	191.6	155.1	52.3	6.5	96.1	0.1			36.5
IS									
NO	137.5	1.1	0.1	0.0	0.8	0.2		1.1	135.3
CH	68.0	1.2		0.2	0.8	0.2	27.9	1.5	37.4

Source: Eurostat, May 2009

* Not including generation from hydro pumped storage, but including electricity generation to pump water to storage. Municipal Solid Waste, Wood waste, Biogas included.

Appendix V – Statistics from the U.S. Energy Information Administration

Table 1.2. Existing Capacity by Energy Source, 2008
(Megawatts)

Energy Source	Number of Generators	Generator Nameplate Capacity	Net Summer Capacity	Net Winter Capacity
Coal[1]	1,445	337,300	313,322	315,461
Petroleum[2]	3,768	63,655	57,445	61,538
Natural Gas[3]	5,467	454,611	397,432	427,703
Other Gases[4]	102	2,262	1,995	1,958
Nuclear	104	106,147	100,755	102,494
Hydroelectric Conventional[5]	3,996	77,731	77,930	77,694
Wind	494	24,980	24,651	24,698
Solar Thermal and Photovoltaic	89	539	536	455
Wood and Wood Derived Fuels[6]	353	7,730	6,864	6,905
Geothermal	228	3,281	2,256	2,409
Other Biomass[7]	1,412	4,854	4,186	4,263
Pumped Storage	151	20,355	21,858	21,768
Other[8]	49	1,042	942	968
Total	**17,658**	**1,104,486**	**1,010,171**	**1,048,313**

Table 1.3. Existing Capacity by Producer Type, 2008
(Megawatts)

Producer Type	Number of Generators	Generator Nameplate Capacity	Net Summer Capacity	Net Winter Capacity
Electric Power Sector				
Electric Utilities	9,371	632,923	584,908	603,610
Independent Power Producers	5,344	395,594	359,044	373,888
Total	**14,715**	**1,028,517**	**943,951**	**977,497**
Combined Heat and Power Sector				
Electric Power[1]	654	42,937	37,309	40,274
Commercial[2]	639	2,593	2,312	2,407
Industrial[2]	1,650	30,439	26,599	28,134
Total	**2,943**	**75,969**	**66,219**	**70,815**
Total All Sectors	**17,658**	**1,104,486**	**1,010,171**	**1,048,313**

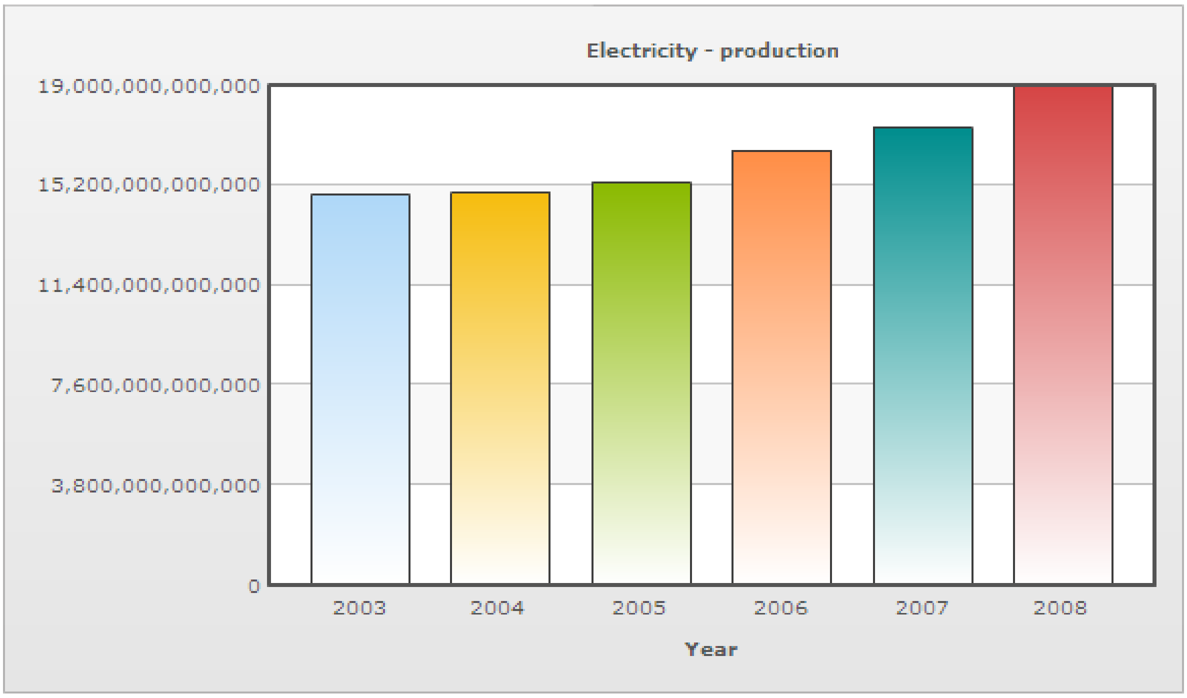
Table 1.6.C. Total Capacity of Dispersed and Distributed Generators by Technology Type, 2004 through 2008
(Count, Megawatts)

Period	Internal Combustion (MW)	Combustion Turbine (MW)	Steam Turbine (MW)	Hydroelectric (MW)	Wind and Other (MW)	Total	
						Number of Generators	(MW)
2004	5,534[R]	1,238	1,637[R]	1,030[R]	140[R]	16,986	9,579
2005[1]	8,315[R]	2,252[R]	1,956[R]	1,001[R]	1,008[R]	28,744	14,532
2006	10,169[R]	1,644[R]	2,739[R]	809[R]	1,088[R]	14,580	16,448[R]
2007	12,490[R]	2,258[R]	3,698[R]	1,082[R]	1,471[R]	18,160	20,999
2008	14,447	2,035	3,308	1,188	1,658	21,853	22,636

Table 1.4. Planned Generating Capacity Additions from New Generators, by Energy Source, 2009-2013

(Count, Megawatts)

Energy Source	Number of Generators	Generator Nameplate Capacity	Net Summer Capacity	Net Winter Capacity
		2009		
U.S. Total	**365**	**27,099**	**24,769**	**25,903**
Coal[1]	13	4,785	4,393	4,419
Petroleum[2]	16	748	695	704
Natural Gas	108	11,388	9,811	10,884
Other Gases[3]	1	78	73	73
Nuclear	--	--	--	--
Hydroelectric Conventional[4]	7	25	24	23
Wind	107	9,459	9,205	9,205
Solar Thermal and Photovoltaic	25	145	134	140
Wood and Wood Derived Fuels[5]	4	139	129	131
Geothermal	4	64	61	61
Other Biomass[6]	80	269	245	264
Pumped Storage	--	--	--	--
Other[7]	--	--	--	--
		2010		
U.S. Total	**228**	**19,841**	**18,081**	**19,021**
Coal[1]	12	5,932	5,598	5,628
Petroleum[2]	13	568	515	545
Natural Gas	78	9,950	8,622	9,498
Other Gases[3]	--	--	--	--
Nuclear	--	--	--	--
Hydroelectric Conventional[4]	10	26	24	24
Wind	40	2,559	2,543	2,543
Solar Thermal and Photovoltaic	13	468	461	462
Wood and Wood Derived Fuels[5]	4	103	96	97
Geothermal	8	168	158	159
Other Biomass[6]	50	66	64	65
Pumped Storage	--	--	--	--
Other[7]	--	--	--	--
		2011		
U.S. Total	**103**	**13,991**	**12,549**	**13,431**
Coal[1]	6	2,837	2,481	2,521
Petroleum[2]	4	200	170	196
Natural Gas	72	8,804	7,545	8,359
Other Gases[3]	--	--	--	--
Nuclear	--	--	--	--
Hydroelectric Conventional[4]	3	7	7	6
Wind	12	1,591	1,588	1,588
Solar Thermal and Photovoltaic	2	375	593	594
Wood and Wood Derived Fuels[5]	1	61	57	57
Geothermal	--	--	--	--
Other Biomass[6]	3	117	109	110
Pumped Storage	--	--	--	--
Other[7]	--	--	--	--
		2012		
U.S. Total	**79**	**20,741**	**18,526**	**19,566**
Coal[1]	12	7,156	6,508	6,581
Petroleum[2]	--	--	--	--
Natural Gas	49	10,208	8,743	9,633
Other Gases[3]	2	720	619	677
Nuclear	1	1,270	1,181	1,194
Hydroelectric Conventional[4]	1	70	67	64
Wind	1	25	25	25
Solar Thermal and Photovoltaic	6	950	1,065	1,070
Wood and Wood Derived Fuels[5]	3	178	166	167
Geothermal	--	--	--	--
Other Biomass[6]	4	164	153	154
Pumped Storage	--	--	--	--
Other[7]	--	--	--	--
		2013		
U.S. Total	**40**	**6,294**	**5,175**	**5,602**
Coal[1]	2	630	562	592
Petroleum[2]	--	--	--	--
Natural Gas	23	5,191	4,167	4,569
Other Gases[3]	--	--	--	--
Nuclear	--	--	--	--
Hydroelectric Conventional[4]	8	245	233	226
Wind	1	16	15	15
Solar Thermal and Photovoltaic	--	--	--	--
Wood and Wood Derived Fuels[5]	1	36	34	34
Geothermal	4	156	146	147
Other Biomass[6]	1	20	19	19
Pumped Storage	--	--	--	--
Other[7]	--	--	--	--



Year	Electricity - production	Rank	Percent Change	Date of Information
2003	14,850,000,000,000	0		2001 est.
2004	14,930,000,000,000	0	0.54 %	2001 est.
2005	15,290,000,000,000	0	2.41 %	2002 est.
2006	16,540,000,000,000	0	8.18 %	2003 est.
2007	17,400,000,000,000	0	5.20 %	2004 est.
2008	18,960,000,000,000	0	8.97 %	2007 est.