Validation and verification of service products

Master´s thesis
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In cooperation with:

ANDRITZ AG

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Kurzfassung

Der customer value ist definiert als der Wert, den ein Kunde vom Anbieter erhält, oder, genauer gesagt, der Betrag, der jedes Jahr eingespart werden kann, wenn ein Produkt von - in diesem Fall - ANDRITZ AG verwendet wird. Diese Masterarbeit konzentriert sich in erster Linie auf den "value for the customer", der nur ein Aspekt des Kundennutzens ist, der andere ist der "value of the customer". Dieses Thema wird jedoch nur kurz erwähnt, um dem Kundenwert eine Vollständigkeit zu geben. Der "value for the customer" wird deshalb näher erläutert, um der ANDRITZ AG eine Argumentationsbasis für den Vertrieb der Produktgruppe Serviceprodukte zu geben.

Auf Grund der Kunden der ANDRITZ AG und ihres Tätigkeitsbereiches wird im B2B-Bereich geforscht, wobei sich der praktische Teil auf die Berechnung des "value for the customer" und die reformierung der Emissionsregulierung für große Feuerungsanlagen konzentriert. Im Jahr 2020 wird die Reform der Emissionsverordnung in Kraft treten. Dies ist der perfekte Zeitpunkt für die ANDRITZ AG, um den Betreibern von Kesselanlagen Änderungen zu bieten, um die neuen Emissionsstandards zu erfüllen. Daher wird dieses Thema auch in dieser Arbeit behandelt. Die Emissionsvorschriften sind in zwei Teilen des praktischen Kapitels zur Problemlösung dargestellt. Zunächst werden die Emissionsvorschriften in den Berechnungen des "value for the customer" erwähnt. Der Versuch, monetarisierte Vorteile zu berechnen, wurde jedoch später aufgegeben, da Kesselbetreiber ihre Anlage ohnehin an die Emissionsstandards anpassen müssen. Daher ist der Ansatz einer Ersatzinvestition als unzureichendes Argument eingestuft worden für den Verkauf von Modifikationen. Der zweite Teil befasst sich mit der Emissionsregulierung selbst, wobei die alten und die neuen Emissionsstandards verglichen und Maßnahmen zur Einhaltung der vorgegebenen Standards diskutiert werden. Die Emissionsnormen wurden dem BREF-Dokument (Best Available Techniques Reference) entnommen. Darüber hinaus wird in diesem Kapitel die Investition beschrieben, die für eine Anpassung and die Emissionsvorschriften erforderlich ist.

Der Wert für den Kunden wird nicht nur für die Emissionsvorschriften berechnet, sondern auch für alle Produkte der ANDRITZ AG welche in der Produktgruppe powerplant services definiert sind. Die Methoden zur Durchführung der Berechnungen und ihre Entwicklung werden diskutiert.

Das Modell, mit dem die Vorteile definiert und die Berechnungen abgeleitet werden, ist im theoretischen Abschnitt enthalten. Darüber hinaus werden dort die unterschiedlichen Emissionen von Großfeuerungsanlagen diskutiert.

Die Fertigstellung der Arbeit hat gezeigt, dass eine korrekte und genaue Übersetzung von Vorteilen in Geldeinheiten eine große Herausforderung darstellt. Die Berechnungen können wegen der Vielzahl an Einflussfaktoren und vor allem auf Grund der stark situationsabhängigen Bedingungen nur sehr schwer generalisiert werden. Eine weitere Hürde bei der Berechnung des „value for the customer“ stellt die Komplexität der Vorteile dar, welche verringert werden musste, damit die Verständlichkeit der Argumente gewährleistet ist.

Gleichzeitig sollten aber möglichst viele Einflussfaktoren berücksichtigt werden um ein möglichst realitätsnahes Bild der Vorteile zu schaffen.

Abstract

The customer value is defined as the value a customer receives from the provider or, more explicitly, the amount of money that can be saved each year when using a product from – in this case – ANDRITZ AG. This master thesis focuses primarily on the 'value for the customer' which is just one aspect of the customer value, the other being the 'value of the customer'. However, this topic is only mentioned briefly in order to provide a completeness to that of customer value. The reason why the 'value for the customer' is discussed in greater detail, is to provide ANDRITZ AG with a basis for argumentation for the sales division of the product group service products.

On behalf of the customers of ANDRITZ AG and the area they are working in, research is being conducted for the B2B sector, whereby the practical section focuses on the calculations of the 'value for the customer' and the reform of the emissions regulation for large combustion plants. In 2020 the reform of the emissions regulation will become effective. This is the perfect moment for ANDRITZ AG to step in and offer boiler operators modifications in order to meet the new emissions standards. Hence, this topic is also covered by this thesis. The emissions regulations are presented in two parts of the practical problem-solving chapter. First, the emissions regulations are mentioned within the calculations of the 'value for the customer'. The attempt to calculate monetarised benefits was, however, later abandoned due to the fact that boiler operators are required to adapt their plant to the emissions standards anyway. Thus, the approach of a replacement investment that has been tried, is an insufficient argument for selling modifications. The second part deals with the emissions regulation itself, whereby the old and the new emissions standards are compared, and measures to meet the prescribed standards discussed. The emission standards were taken from the Best Available Techniques Reference Document (BREF). Furthermore, the investment that needs to be made for a certain modification is described in this chapter.

The value for the customer is not only calculated for the emissions regulations but more importantly for all products offered by ANDRITZ AG´s product group powerplant services. The methods used to perform the calculations and how they evolved are discussed.

The model used to define the benefits and derive the calculations is included in the theoretical section. In addition, the different emissions of large combustion plants are discussed there.

The completion of the work has shown that a correct and accurate translation of benefits in monetary units is a great challenge. The generalization of the calculations is very difficult. The reason is the large number of factors one advantage influences and above all the strongly situation-dependent conditions. Another hurdle in the calculation of "value for the customer" is the complexity of the benefits that had to be reduced in order to ensure the comprehensibility of the arguments. At the same time, as many influencing factors as possible should be taken into account in order to create a realistic picture of the benefits.

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1 Introduction

In order to provide a sound basis to this master thesis the purpose and the aim of the research are described below. Initially, the approach needed to achieve the targets could not be explicitly defined, but as research progressed the picture became clearer enabling a concept to be developed.

1.1 Initial Situation

ANDRITZ AG was founded in 1852 as a small iron foundry which formed the foundations for the growth and development of the company as it is today. The company consists of various divisions such as ‘Hydro’, ‘Pulp and Paper’, ‘Separation’ and ’Metals’. The service department of Andritz AG Pulp & Paper, which is based in Raaba in Graz, offered master theses to improve their sales division. However, this master thesis commenced in the product group power plant services, where ANDRITZ AG is currently applying a service market for fluidised bed boilers sold in the pulp and paper division. Since the sale of service products is a relatively new field for the enterprise, the purpose of this master thesis is to help develop both a sales strategy as well as the arguments needed to successfully sell the products. ANDRITZ AG already boasted a portfolio of service products and modifications that are sold in order to improve an existing plant, or to acquire a long-term customer relationship.

The company had no experience of selling services since they focused primarily on the sale of real engineering products. Moreover, no documentation of a sales strategy and the associated benefit arguments exist, and these should now be defined.

A further reason why this thesis was generated is that in 2020 the emissions regulations are being changed to a lower threshold, providing the optimum way to sell modifications since the regulations need to be met anyway. This section was mainly derived from the BREF document.

1.2 Targets

This master thesis is concerned with dollarization, a fabricated term for translating the advantages of a product or service into real arguments expressed in euros, or describing the advantages in the most compensable way. The target is to create Excel sheets showing the ‘customer value’ a company can receive when buying an ANDRITZ AG service package, upgrade or modernization for their existing fluidised bed plant.

ANDRITZ AG needs a new approach to gaining offers, since in previous years the company waited for a job to be tendered. This strategy is no longer practical due to a high level of competition. As a result, ANDRITZ AG has changed its tactics from waiting to being active in its relations to the customer. The changes in sales call for a new sales strategy. What is needed is a guideline and arguments to be able to follow the guideline. For ANDRITZ AG this master thesis provides a basis for precisely that.

1.3 Task

Hence the requirements for the ‘value for the customer’ were clear:

- Defining the ‘customer value’;
- Explaining the operation of the fluidised bed boiler;
- Finding advantages;
- Comparing the advantage with something (for example: the costs for sand due to the usage of bed material recirculation compared to the costs for sand without bed material recirculation);
- Calculating such using cognitive algebra;
- Summarising the savings for each product;
- Visualising the monetarised value using diagrams.

The tasks for the case of emissions regulations are:

- Identifying both the new and the old emissions standards for large combustion plants according to the Best Available Techniques Reference Document;
- Deriving and categorising the extent of reduction to be fulfilled;
- Defining and explaining the measures to meet the requirements;
- Estimating the investment for associated modification.

1.4 Area Surveyed

For the ‘customer value’ the scope was initially limited to the service products and later all of the ‘Replacement^{plus}‘ products. However, the list of products was limited due to the high variety of products. The limitations were made using a flyer ANDRITZ AG sent to its customers listing the products that can be purchased. In a technical context, it was agreed to look at CFB and BFB boilers only. Since ANDRITZ AG sells medium-sized boilers, the limitations of minimum 50 MW_{th} and maximum 350MW_{th} for the boiler performance were obvious.

For the issue of emissions, the restrictions are limitations in pollutants and fuels. The Excel sheet discusses the emissions of SO2, NOx, and dust polluted by the most important combustibles, biomass/peat, gas, coal/lignite and solid waste.

1.5 Approach

The approach used to translate benefits into monetary values was derived from a broad literature research. The benefits were collected from internal data and later checked for validity. Subsequently Excel sheets to calculate the value in euros were set up. To derive the boiler operating parameters needed for the calculations, numerous interviews were conducted with specialists in CFB and BFB boiler operation and handling. However, the vast knowledge of Dr. Ulrich Hohenwarter, the supervisor of this thesis, made it possible to derive and quantify all the benefits with respect to the product characteristics.

Of course, qualitative benefits were also found that will help the sales division on an emotional basis because translating them was impossible. The emotional benefits though are the real advantages in comparison to the competition.

2 Theoretical Background

Within this section the most important literature related to the topic is discussed. First the concept of ‘customer value’ is explained. Many different opinions with even more different names exist on this subject. Hence, the different approaches are briefly illustrated to provide an overview of the ‘customer value’.

The target of the ‘customer value’ section of this chapter is to explain various views, but it mainly focuses on the value for the customer, which describes the view of the customer and the benefit received. It should also furnish an insight into how to derive the variables needed together with a rough step-by-step plan on how to walk through the determination process. Moreover, an example of a sales talk is included to show the necessity of benefits and to ensure they are communicated appropriately.

The second part deals with emissions polluted by large combustion plants and how to reduce these. Creating electric or steam energy also creates a huge number of harmful molecules and greenhouse gases. What kind of pollutant and why it is created is explained later.

2.1 The Perspectives of the ‘Customer Value’

In the German and English literature, two different views of the ‘customer value’ exist. One is the ‘value for the customer’ and the other is the ‘value of the customer’.

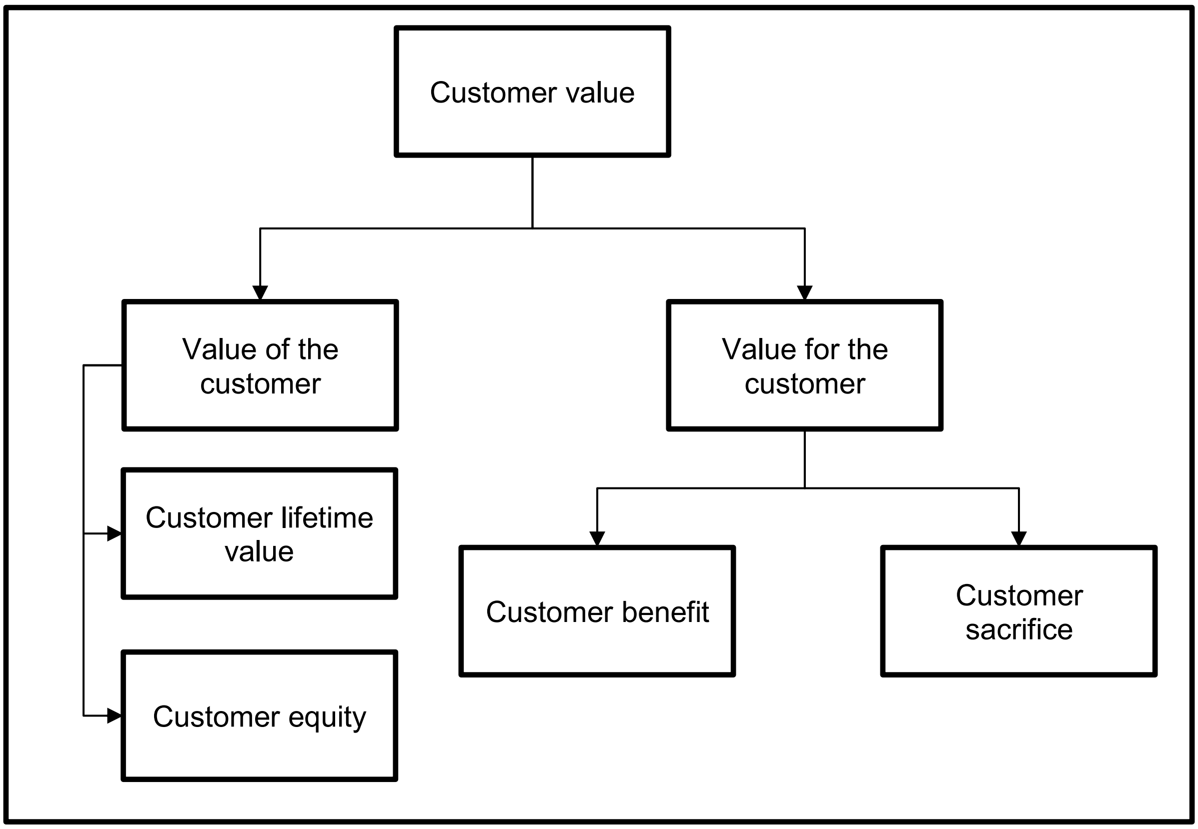


Figure 1: The structure of the ‘customer value’

The first term signifies the value a product creates, which means that the product sold by a company creates a value a customer receives when buying or using it. This view and its components can be seen in Figure 1 and is described in detail within the next chapters. It is termed ‘value for the customer’.

The second topic is concerned with the value a company receives, and is termed ‘value of the customer’. It focuses on the amount of money a company can make during the relation with a potential customer. For strategic decisions such as key account management or customer relationships, this perspective is a highly important tool. However, it is not described in detail within this master thesis as it does not form the main topic of this scientific paper.

2.2 The ‘Value for the Customer’

2.2.1 Definition of the ‘Value for the Customer’

In the German language terms such as “customer-net-benefit”, ‘Nettonutzenvorteil’ or ‘Nettonutzendifferenz’, ‘wahrgenommener Kundenwert’ or even ‘Wertgewinn’ are used. For an understanding of these terms, a translation is given in Table 1 below.[1]

[1] Cf. SEERINGER, C. (2010), p. 70.

Terms used	English translation	Author	Definition of the term
German terms:			
Erwarteter bzw wahrgenommener Nettonutzen des Kunden	Expected or perceived net benefit of the customer	Eggert (2001), p. 46 f.	„[…] the result of the alignment between the benefit sum and the expense sum, which a customer expects ex ante or perceives ex post, in the event of a transaction.“
Kundennettonutzen	Customer net benefit	Hundacker (2005), p. 66 f.	„According to the principle of cognitive algebra, customers compare the positive and negative perceptions of benefits and form an overall assessment of the net benefit.”
	Customer net benefit	Messner (2005), p. 26	“[…] the quantity of offers from the total supply of a company deliberately perceived by the customer, taking into account available offers of competition and pricing.”
Relativer Nutzenvorteil (Nettonutzendifferenz)	Relativ benefit advantage (net benefit difference)	Plinke (2000), p. 78 f.	The provider A is chosen if the net benefit to the buyer (the benefit-cost-difference) is greater for him at A than the net benefit of the competitor of the provider Relativ benefit $\text{advantage}^{A/AC}$ $= [\text{benefit}^{A} - \text{costs}^{A}] - [\text{benefit}^{AC} - \text{costs}^{AC}]$
Kundenvorteil	Customer advantage	Grosse-Oetringhaus (1994), p. 60	„[…] meet the needs of the customer better than the competitor.“
Wahrgenommener Kundenwert	Perceived customer value	Matzler (2000), p. 293	„The perceived customer value is the ratio of the estimated tangible and intangible costs of an exchange relationship to the perceived tangible and intangible benefits of that exchange relationship. The result of this comparison is related to the perceived costs and benefits of an alternative (competing product or service).”
Wertgewinn	Value gain	Kotler, Keller & Bliemel (2007), p. 43	“The gain in value to the customer results from the difference between the value amount and the cost amount of the offer. If the sum of value predominates, then the provider has created an acceptable value offer.”

Table 1: German definitions and expressions of the ‘value for the customer’[2]

[2] Cf. SEERINGER, C. (2010), p. 71.

In the English literature notions like ‘value for the customer’, ‘perceived customer value’ and ‘customer perceived value’, or also ‘consumer perceived value’ are common. But all have one thing in common: the value for the customer of a product or a service is the difference of expense and value. Or as Zeithamel defined it: the value for the customer is a trade-off between a “give” and a “get”-component of a transaction. The English definitions of the topic are shown in the Table 2.[3]

Terms used	Author	Definition of the term
English terms		
Customer Value	Gale (1994), p. XIV	„Customer value is market-perceived quality adjusted to the relative price.“
	Staat, Bauer & Hammerschmidt (2002), p 206	„CV is the customer´s economic value derived from the product in the sense of an output to input efficiency value. It can be understood as the return on customer investment”
	Huber, Hermann & Morgan (2001), p. 45	“[…] customer value is a consequence of a subjective evaluation which in turn results from the summing of the various elements contributing to the perceived fulfilment of the value, benefit, and attribute level and perceived costs, taking into account subjective factors”
	Anderson & Narus (1998), p. 54	„Value in business markets is the worth in monetary terms of the technical, economic, service, and social benefits a customer company receives in exchange for the price it pays for a market offering.“
Perceived (Customer) Value	Zeithaml (1988), p. 14	“Perceived value is the customer´s overall assessment of the utility of a product based on the perceptions of what is received and what is given.”
	Sinha & DeSarbo (1998), p. 237	“Perceived value is clearly a multidimensional construct derived from perceptions of price, quality, quantity, benefits, and sacrifice […]”
Customer Perceived Value	Eggert & Ulaga (2002), p. 110	“[…] the trade-off between the multiple benefits and sacrifices of a supplier´s offering, as perceived by key decision-makers in the customer´s organization, and taking into consideration the available alternative suppliers´ offerings in a specific use situation”
	Gönroos (1997), p. 411 f.	“Customer Perceived Value (CPV) = (Core Solution + Added Services) / (Price + Relationship Costs)”
Net (comparative customer) value	Carothers & Adams (1991) p. 34	Value is defined as that value realized by a customer which justifies the sacrifice made to acquire, use, and dispose of a product/service, in comparison to available alternatives.”

Table 2: English definitions and expressions of the ‘value for the customer’[4]

[3] Cf. SEERINGER, C. (2010), p. 70.
[4] SEERINGER, C. (2010), p. 73.

The components of the value for the customer are defined differently within the literature. For Gale (1994) for example, the 'value for the customer' consists of the ratio of relative 'customer benefit' and relative costs.[4] When analysing Diagram 1 one can see that if the relative 'customer benefit' is lower than a certain minimum, the product will not be sold even if the price is minimal.[5] However, the disadvantage of this view is that there is no differentiation between dimensions and factors.

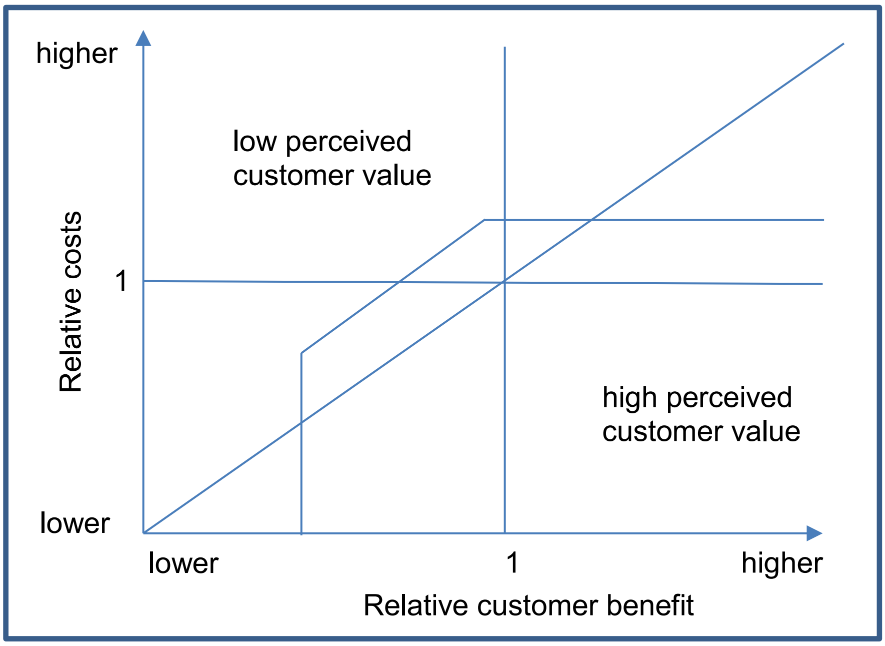


Diagram 1: Visualisation of the 'customer value' according to Gale[6]

In the literature, the terms customer benefit for the get-component and customer sacrifice for the give-component are established and will be used in this master thesis. Whereas the 'customer benefit' refers to the monetary savings realised by the advantages of the products, the 'customer sacrifice' refers to the expenses rated in euros to purchase a product. The alignment of customer benefit and customer sacrifice with the 'value for the customer' as result happens individually by the customer itself using simple algebra while considering subjective weighting factors. Keeping the benefits simply comprehensible and transparent is crucial in order to let the customer see the amount of savings.[7] They should be able to recalculate the benefit without a calculator. The reason is that the statement of the salesman can be verified by the customer. Furthermore, the salesman may briefly explain the calculations performed if comprehension issues arise.

In particular, in the B2B area the individual components of the 'value for the customer' equation can possibly be quantified or monetarised in such a way that an explicit offsetting of benefits and costs is possible. For example, a reduction of the customer sacrifice by a new production line can be expressed with time savings or savings on maintenance work.[8] However, the monetisation of social benefits, which Anderson and Narus include in their definition, seem particularly difficult. For the customer as an end consumer, hence the B2C area, quantifying

[5] Cf. SEERINGER, C. (2010), p. 73.
[6] Cf. BELZ, C.; Bieger, T. (2004), p. 97.
[7] Cf. SEERINGER, C. (2010), p. 73.
[8] Cf. SEERINGER, C. (2010), p. 73.

the ’value for the customer’ is usually even more difficult. In reality, the estimation of the extent of the value for the customer is more likely based on an intuitive weighing of customer benefit and customer sacrifice.[9]

There are different approaches in the literature for implicit or explicit accounting of the value for the customer: Some authors describe it using a division model, which is a quotient of benefit and sacrifice, whereas theoretically every result greater than one represents an advantageous value for the customer. Other authors assume a subtraction model in which the difference between benefit and effort represents the value for the customer. In this case, any positive result (greater than zero) represents a beneficial customer value from the customer perspective.[10] In the literature there is no agreement about the question whether divisional or subtraction models represent the sacrifice-benefit comparison more realistically. However, the reason why the subtraction model proves to be a better predictor of buying behaviour in this case was that a denominator going to zero (meaning no sacrifice is made) would imply an infinite value for the customer in the division model, which seems unrealistic. In this scientific paper, the social and emotional benefits were not taken into consideration which would have been possible with the division model. Therefore, the subtraction model should be taken as a basis when considering the value for the customer. Thus, the following formula defines the value for the customer or customer value: [11]

$$Value\ for\ the\ customer = customer\ benefit - customer\ sacrifice$$

Equation 1: Value for the customer[12]

Weinhold in contrast tried to picture the relation as stated in Figure 2, using the offer of the company, the customer needs and the competitive offer, but still defines the ‘value for the customer’ as the sum of benefits minus the sum of disadvantages or, in this case, sacrifices manifested as expenses.

[9] Cf. SEERINGER, C. (2010), p. 74.
[10] Cf. SEERINGER, C. (2010), p. 74.
[11] Cf. SEERINGER, C. (2010), p. 74.
[12] SEERINGER, C. (2010), p. 75.

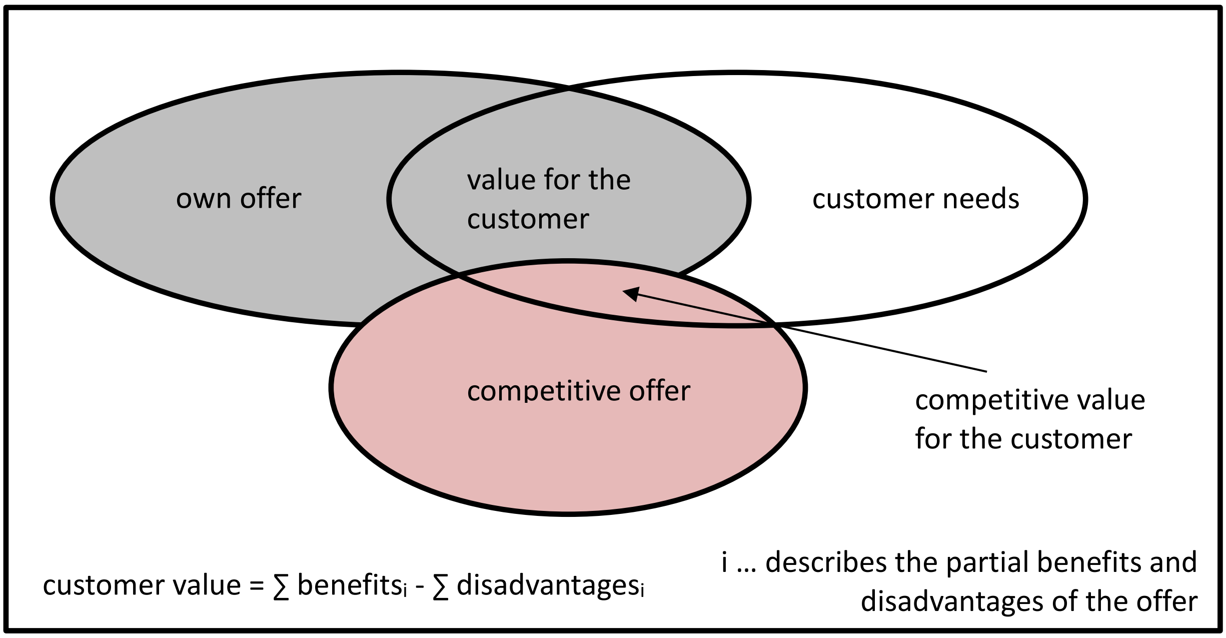


Figure 2: Own adaption of the visualisation of customer value and the degree of satisfaction of the customer needs[13]

In Figure 2 the competitive 'value for the customer' is smaller than the provider's 'value for the customer'. This situation will end in an advantageous response to the provider offer. The competitive value was added to the original picture to show how customers decide which offer to take. In particular, in the B2B area the customer usually compares the offers himself according to the 'value for the customer' because it is extremely hard to determine data from the competitors. Normally competitors do not communicate their advantages or unique selling proposition to other companies in the same field. The reason for this is to sustain their market position and to keep the knowledge in-house in order to prevent their products from being imitated.

The 'customer benefit' as a benefit of a product or service is highly subjective and depends above all on whether the product or service contributes to the fulfilment of customer needs or to the realisation of the individual goals and values of the customer. Current theories attempt to develop more meaningful models of buying behaviour by linking a person's needs to specific goals and purposeful actions in relation to products.[14] At this point, the 'Means-End theory' applies. This is based on the assumption that consumers consider products as a means to reach their goals (ends). The link between the product's attributes and the achievement of goals in the 'Means-End theory' are the consequences of the product usage. The positive consequences of using a product are customer benefits, and potential negative consequences are perceived as a customer sacrifice. A central aspect of the means-end model is the assumption that consumers perform actions that maximise the positive consequences and lead to a minimisation of the negative consequences.[9]

Figure 3 represents the 'Means-End schema' which describes the process of an arising need to its satisfaction as well as the comparison of the perceived benefit with the degree of

[13] Cf. BELZ, C.; BIEGER, T. (2004), p. 192
[14] Cf. SEERINGER, C. (2010), p. 75.

fulfilment of the goal of the customer. The customer then memorizes the consequence as positive or negative, which influences his future buying behaviour.[15] In the B2B area and especially in the field of fluidised bed boilers, the goals are usually a most efficient operation and at the same time lowest operation costs. For the maintenance of a fluidised bed boiler and the service of a plant, the goal would be the lowest shutdown time at the lowest maintenance costs. This thinking, adopted to determine the 'customer benefit' of ANDRITZ AG products, helped define the right product advantages and to translate them into real 'customer benefits'.

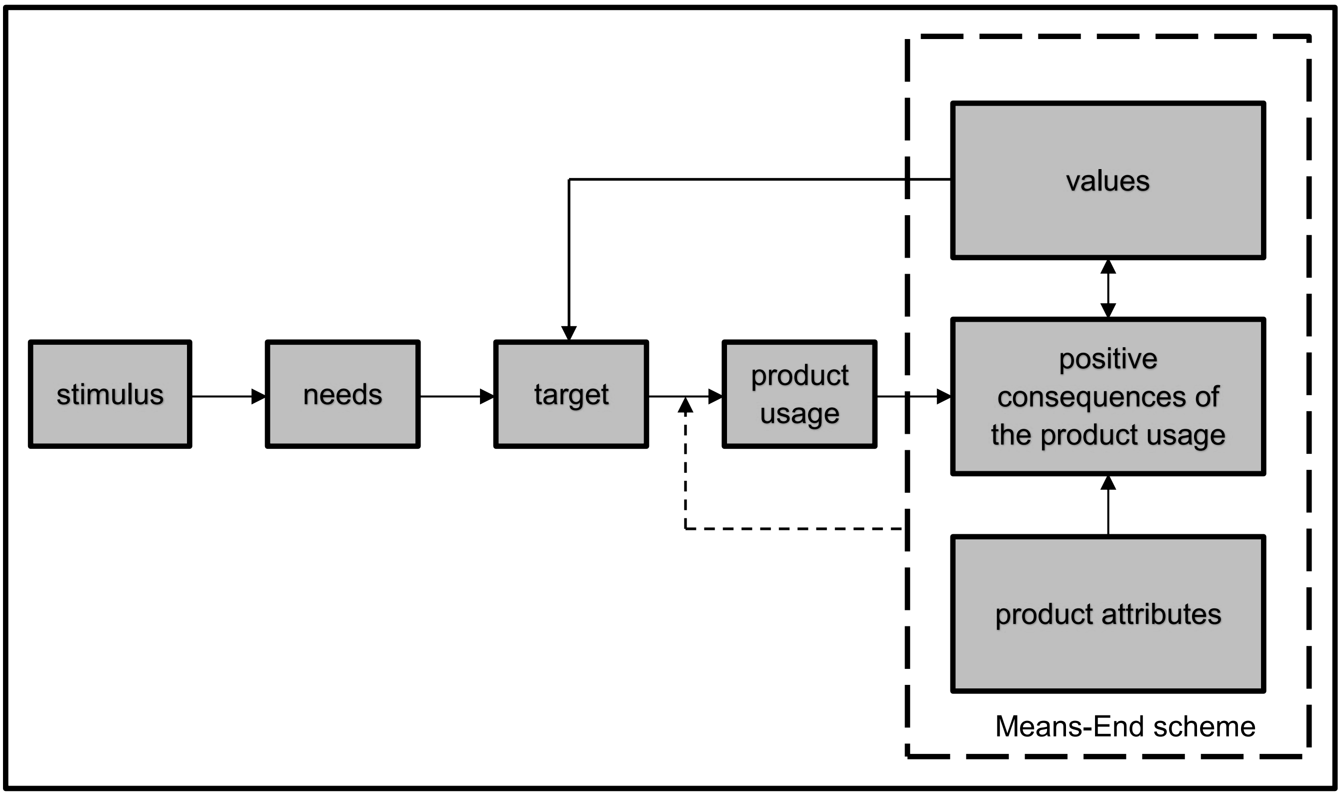


Figure 3: Customer benefit within the Means-End Scheme[16]

2.2.2 The model used to determine the 'Value for the Customer'

This chapter describes the model used to determine the product benefits and thereafter the 'customer benefit'. Firstly, the types of benefits and the categories for distinguishing these benefits are specified.

2.2.2.1 The categories of the model (citation)

As described in point 2.2.1 the 'customer benefit' is the value of the relevant customer specific advantages expressed in euros. In its sum, the 'customer benefit' is the counterpart to the price, respectively to the 'customer sacrifice', and has various levers as well as dimensions. This model was chosen because of the predefined tables which simplified the translation of

[15] Cf. SEERINGER, C. (2010), p. 76.
[16] Cf. SEERINGER, C. (2010), p. 80.

product advantages into monetarised benefits by a step-by-step abstraction from advantages to benefits, and via buying motifs to monetary rated benefits. It also provided a distinction whether the benefit can be calculated or not: if the benefit acts on an emotional basis or not, which is crucial for sales arguments. In Figure 4: The benefit model, the three benefit types of product benefit, usage benefit and additional benefit (also called added value) and their dimensions are outlined. Every benefit has different dimensions according to which it can be categorised. One dimension categorises the benefit either on an emotional, rational or social level. The second dimension distinguishes between measurable, calculable and/or decidable benefits. [17] Here a link on how to determine the monetarised 'customer benefit' in the calculations can be seen. A more detailed description of the categories follows:

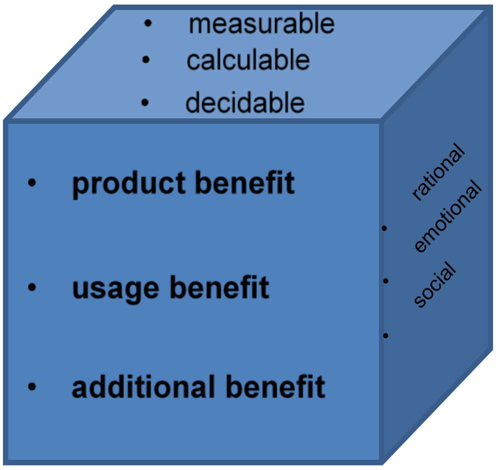


Figure 4: The benefit model[18]

Rational:
The benefit from experience, or intellectually plausible, comprehensible (measurable, calculable, observable,)[19]

Emotional:
Emotionally perceptible or conceivable and possibly rationalisable benefits (recognition, pleasure, innovation, performance, quality, safety,)[20]

Social:
The community-serving value (teamwork promoting, ecologically degradable,)[21]

For a well-structured calculation every benefit can further be distinguished according to whether the 'customer benefit' is measurable, calculable or decidable:

[17] Cf. MENTHE, T.; SIEG, M. (2013), p. 109
[18] Cf. MENTHE, T.; SIEG, M. (2013), p. 110.
[19] Cf. MENTHE, T.; SIEG, M. (2013), p. 109.
[20] Cf. MENTHE, T.; SIEG, M. (2013), p. 109.
[21] Cf. MENTHE, T.; SIEG, M. (2013), p. 109.

- **Measurable**, for example, is the higher throughput of a machine or the increase in incoming orders with an employee. However, this can also be accomplished by complementary measures (for example, promo action);

- **Calculable** would be the economy of time (time=money) with the minute factor or the valuation of a higher employee motivation and its translation into an efficiency improvement (satisfied employees work harder);

- **Decidable** would, for example, be to what extent the convincing occurrence of the salesman, the additional benefit offered, or the higher customer satisfaction effect the revenue and profit increase.[22]

As described previously, the benefit in this model is classified into three categories:

- Category I: measurable - savings, growth, etc.
- Category II: calculable -productivity increase, savings, etc.
- Category III: decidable - qualitative, immaterial, strategic, etc.[23]

Measuring the factors of category I is simple. Methods to do so would for example be:

- Measuring (e.g.: low use of space, area, energy, time, etc.),
- Counting (e.g.: persons, revenue, costs, machine throughput, etc.),
- Weighing (e.g.: material, etc.)[24]

The benefits of category II might be

- Machined (e.g.: higher productivity, etc.)
- Calculated (e.g.: possible growth due to higher capacity, etc.)
- Presumed (e.g.: higher demand/sales volume due to climate change, etc.)[25]

In category III the benefit is predominantly

- Estimated and presumed.[26]

While Categories I and II focus primarily on hard facts and increased profits, the benefits of Category III tend to be in the area of soft factors and performance increase.[27]

Table 3 shows various resulting benefits for each category (measurable, calculable, and decidable). For example, a reduction in maintenance effort may result in savings of material, personnel and energy.

[22] Cf. MENTHE, T.; SIEG, M. (2013), p. 109 f.
[23] Cf. MENTHE, T.; SIEG, M. (2013), p. 120.
[24] Cf. MENTHE, T.; SIEG, M. (2013), p. 120.
[25] Cf. MENTHE, T.; SIEG, M. (2013), p. 120.
[26] Cf. MENTHE, T.; SIEG, M. (2013), p. 120.
[27] Cf. MENTHE, T.; SIEG, M. (2013), p. 120.

Benefit arguments derived from the initial benefits for each category:		
Category I Measurable saving, growth	Category II Calculable productivity increase	Category III Decidable qualitative, strategic

Direct saving of costs and time
• space
• energy
• material
• personnel
• machines
• …
Increase of
• sales
• revenue
• throughput
• …
	Saving of future costs and time due to
	• growth
	• higher productivity
	• changes, for example
	   • organisation
	   • laws
	   • market etc.
	• …
		Elusive benefit consisting of a secondary effect, qualitative, immaterial advantages and higher performance and competitiveness
		• more accurate, faster information
		• enhanced planning
		• higher employee satisfaction
		• faster reaction
		• higher customer satisfaction
		• …

profit increase	performance increase	

Table 3: Examples of customer benefits (according to Kurt Nagel)[28]

As shown in Figure 5, the issue of 'customer benefit' also provides many starting points, not only to increase the attractiveness of the offer, but also to differentiate itself from the competition and thus to increase the 'value for the customer'.[29]

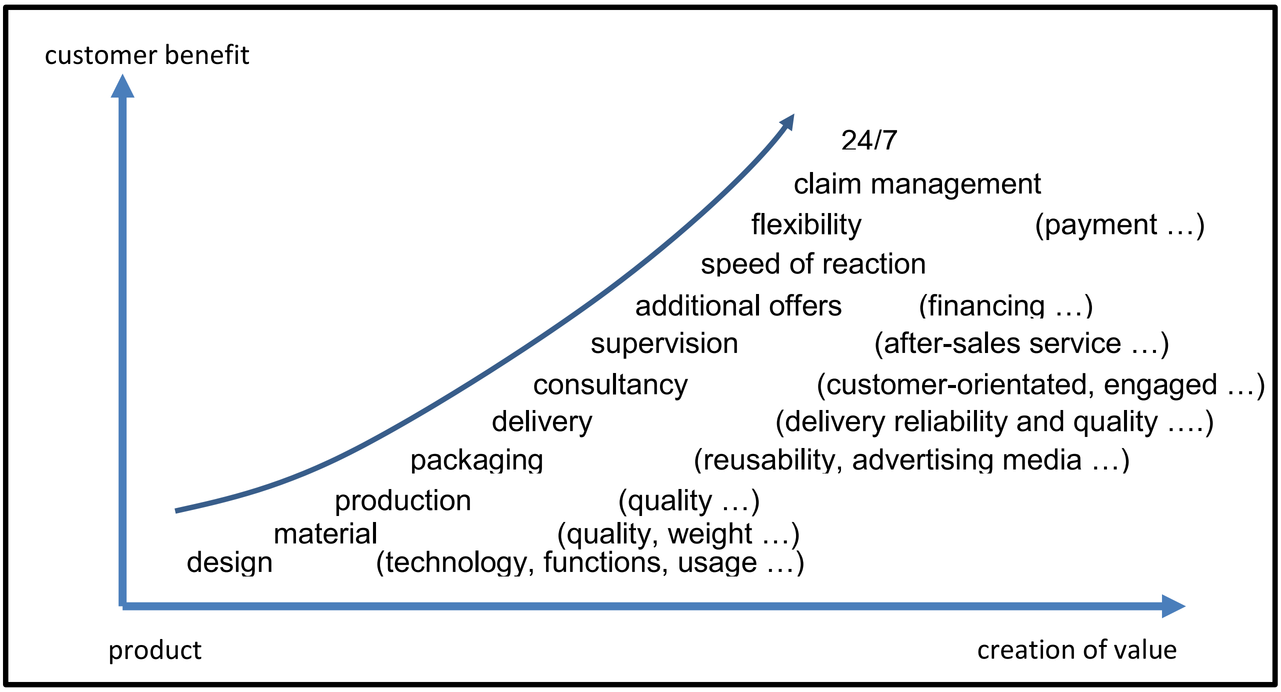


Figure 5: Relationship of value and benefit[30]

[28] Cf. MENTHE, T.; SIEG, M. (2013), p. 112.
[29] Cf. MENTHE, T.; SIEG, M. (2013), p. 110.
[30] Cf. MENTHE, T.; SIEG, M. (2013), p. 112.

2.2.2.2 The concept of the model for the 'Value for the Customer'

The first step towards benefit determination is to describe all product characteristics (properties, functions, performance characteristics) as benefits (= possible improvement of the as-is situation). Each advantage contains many benefit aspects. The benefit aspects relevant for the customer are derived from the customer's motifs. The model is performed individually for every product in the form of the pattern illustrated in Table 4:[31]

* Category: m = measurable, c = calculable, d = decidable

sample product							
pos.	product characteristics	advantages	benefits	category* m	c	d	motif
1	clockwise/ anti-clockwise	versatility	fewer tools/ investment	1			ROI
2		clean drill hole	time saving	1			ROI, comfort
3		turn screw in/out	time saving	1			ROI, comfort
4							
			sum	3			

Table 4: Reference model to determine the 'value for the customer'[32]

The number of positions depends on the variety of product characteristics, advantages, benefit aspects and motifs. The more benefit aspects one has and the more customer motifs one can satisfy, the bigger the pot from which the salesman/woman can draw out effective benefit aspects during the sales conversation.[33] This basic table acts as the bedrock for the calculations discussed in chapter 3.5 and is further modified to meet the requirements and restrictions of the B2B area.

In section 2.1 the benefit was defined as the customer-relevant advantages expressed in euros. The aim of the benefit determination is to translate all benefit aspects into monetary values and picture them as 'value for the customer'. In particular, Category III is very important because experience has shown that about 80% of the customer decisions are influenced by precisely these aspects. [34]

Table 4 can further be extended by the relevance (high, medium, low). The relevance of the benefit is in practice an indication of the importance for the customer of the underlying motif. The five most important motifs are:

- savings,
- security,

[31] Cf. MENTHE, T.; SIEG, M. (2013), p. 119.
[32] Cf. MENTHE, T.; SIEG, M. (2013), p. 119.
[33] Cf. MENTHE, T.; SIEG, M. (2013), p. 119.
[34] Cf. MENTHE, T.; SIEG, M. (2013), p. 120.

- profit,
- convenience,
- image / prestige,
- health / competitiveness (people/ companies).[35]

In companies with various customers, or in the B2C area, this column is useful for decreasing the amount of benefits and focusing on the most important ones. It is a perfect basis to tailor the benefits to regarded customer. However, the problem of this column is that a lot of information about the customer is necessary, and this is often hard to determine particularly in the B2B area. This is the reason why the most important motifs used in the practical problem-solving section are defined differently using the terms:

- cost savings
- profit increase
- higher reliability and due to the issue of emissions regulations discussed in the paper
- emissions standards

Table 5 shows the extended version of the reference model.

Reference Model for Sample Product											
pos.	product characteristics	advantages	benefit	category			relevance			motif	potential value in euro
				m	c	d	h	m	l		
1											
2											
3											
4											
			sum								

Table 5: Extended reference model to determine the 'value for the customer'[36]

Basically, regardless of the category, all benefit aspects may be assigned to one of the following two classes:

- Euro (money)
- Time (also equals money)

[35] Cf. MENTHE, T.; SIEG, M. (2013), p. 121.
[36] Cf. MENTHE, T.; SIEG, M. (2013), p. 121.

2.2.3 Calculation models for the translation of benefits into monetary values

By using the template shown in Table 5, a reference model for a specific product with all product characteristics, advantages, benefit aspects and the potential value can be established. The reference model can quickly exceed 50 positions and can easily be adjusted to the respective acquisition project. But how can the benefits be translated into monetary values? Within Category I *Measurable* this is easy. Everything that is produced or sold has its own value expressed in euros, new customers acquired, material saved, personnel and so on.[37]

The following sections provide an overview of how the benefits can be translated into monetary values. The calculations may vary for each project, or simply cannot be used for certain advantages. Maybe new schemes need to be created as can be seen in section **Error! Reference source not found.**

2.2.3.1 The minute factor

The minute factor continues to have an impressive effect. In order to demonstrate its impact, an example calculation will now be discussed. For a better understanding of the example a table containing the values is provided below. The schema pictured in Table 6 offers an easy way to calculate the minute factor and absorb it into the calculation of the 'customer benefit'. [38]

pos.	cost type	example	individual
1	monthly gross wage	4000 €	€
	x 13 months	52000 €	€
2	sales bonus p.a.	8000 €	€
3	**sum**	**60000 €**	€
4	directly accountable ancillary costs about 35% of 3	21000 €	€
5	**sum 3 + 4**	**81000 €**	**€**
6	supplement for proportional operation costs 50% of 5	40500 €	€
7	other grants p.a.	2000 €	€
8	**total sum**	**123500 €**	**€**
9	regular annual working hour 220 days x 8 hrs x 60 min	105600 min.	min.
10	**minute factor = pos. 8 /pos. 9**	**1.17 €**	**€**

Table 6: The minute factor (according to Meier-Maletz)[39]

[37] Cf. MENTHE, T.; SIEG, M. (2013), p. 121.
[38] Cf. MENTHE, T.; SIEG, M. (2013), p. 122.
[39] Cf. MENTHE, T.; SIEG, M. (2013), p. 122.

On the assumption that 200 workers needed 1 minute less due to some training or procedural changes, this would result in a profit increase (at a minute factor of € 1.17 in accordance with Table 6) of € 51,480 (= 200 workers x 220 working days x € 1.17). If this were increased to 5 minutes each day, a productivity increase of € 257,400 per year would be generated. The question then arises what the time saved would be used for. Probably for a sophisticated or valuable task, meaning better time usage can further increase the value. The 733 h saved (200 workers x 220 working days x 1 min. = 44000 min. divided by 60) can be used for selling for example. How many new customers or additional contracts could be won and with which contribution margin? Not all of the 200 workers are sellers. Yet every employee (including the manager) is part of the sales force of the company due to his or her work and performance. Finally, the workers, with their creativity, are the ones developing attractive products and service products, defining and deciding the processes within the corporation and where to use which sales strategy. They determine the organisation and ensure it works. It is they who are responsible for the quality, availability and the punctual delivery of the products, the service and the 'value for the customer' that the company offers, as well as for the way the business processing is organised and performed. All these attributes play a role and are the arguments or the so-called munition, for the sales force.[40]

Hard facts are just one aspect of the 'customer benefit'. The other represents the soft facts perceptible on an emotional basis. Translating these soft factors to monetary values can often be difficult. An example of how it may be done is discussed in the next section.[41]

2.2.3.2 The translation of soft factors into monetary value

As previously stated, the benefit criteria within category III primarily represent soft success factors and immaterial or qualitative aspects. These can often be calculated as a saving of time and/or money. In the following example 'employee satisfaction' one possible calculation schema is shown.[42]

Employee satisfaction example: The monetary values, listed in Table 7, are mainly savings in time and costs derived from soft factors such as increasing productivity, greater engagement and so on. The values for time saving are calculated by the time saved, the number of employees and the costs of a minute. In the case of cost reduction due to fewer mistakes a value per mistake is assumed and multiplied by the reduction of mistakes. Some factors can simply be estimated like a cost reduction due to more ideas, but in the end a huge saving of money can be determined. The values written in Table 7 are assumed, and are merely intended to provide a comprehensible example.

[40] Cf. MENTHE, T.; SIEG, M. (2013), p. 122 f.
[41] Cf. MENTHE, T.; SIEG, M. (2013), p. 123.
[42] Cf. MENTHE, T.; SIEG, M. (2013), p. 123.

soft factor (decidable benefit): customer satisfaction		potential value (1 year)					
has an effect on			euro	minutes	min.-factor in euros	min.-euros	total in euros
	aspect	factor					
1.	productivity	amount: 5 orders	25,000	0	0	0	25,000
2.		time: 25 emp. x 10 min/day	0	55,000	1.34	73,700	73,700
3.	less talk	time: s. 2 and 3.	0	0	0	0	0
4.	more motivation	time: 30 emp. x 5 min/day	0	33,000	1.34	44,220	44,220
5.	fewer mistakes	costs: 5 emp. x 1 mistake/week	45,000	0	0	0	45,000
6.		time (25 emp. x 10 min/week)	0	11,250	1.34	15,075	15,075
7.	more ideas	cost reduction	5,000	0	0	0	5,000
8.		time saving	0	1000	1.34	1,340	1,340
9.		revenue increase	10,000	0	0	0	10,000
		TOTAL	85,000	100,250		134,335	219,335

Table 7: example employee satisfaction[43]

This example cannot be applied to every soft factor but is a good sample for envisaging the impressive effect of the minute factor. The minute factor, however, is just a small aspect of the total 'customer value' calculations stated in section 3.5. Therefore, it is not discussed separately but is included in the calculations.

[43] Cf. MENTHE, T.; SIEG, M. (2013), p. 124.

2.2.3.3 The value comparison method

The value comparison method is another procedure to derive the decidable or qualitative benefit and translate it into euros. The basis of this method is the directly measurable and calculable benefit. The 5 work steps required are depicted in Table 8.[44]

1.	**benefit due to higher revenue/new customers/ higher offer transition rate**	€ 75,000				
2.	**listing of quantitative criteria**	**4.**	**rating of the benefit elements**			
		low		medium		high
		1	2	3	4	5
	revenue increase				x	
	new customers		x			
	higher offer transition rate			x		
3.	**listing of qualitative criteria**					
	higher degree of target attainment		x			
	more convincing manner		x			
5.	**determination of the values of the qualitative benefit elements**					
average evaluation of the quantitative criteria 9 / 3 = 3						
average evaluation of the qualitative criteria 4/2 = 2						
allocated value of the quantitative benefit elements:		€ 75,000				
allocated value of the qualitative benefit elements: (2/3 from 75,000)		€ 50,000				
total benefit		**€ 125,000**				

Table 8: Example calculation for qualitative benefits (example training program) (Nagel1994)[45]

Table 8 shows an example of a training program with higher revenue, new customers and a higher offer translation rate as benefits. For evaluating the qualitative criteria, three quantitative

[44] Cf. MENTHE, T.; SIEG, M. (2013), p. 125.
[45] Cf. MENTHE, T.; SIEG, M. (2013), p. 125.

and two qualitative criteria were initially identified, and used to calculate the value comparison and the benefit. [46]

2.3 Technical Background of Fluidised Bed Boilers

The overall concept of firing natural resources or waste is that heat is created by burning the fuel. In the burning chamber of the boiler, the heat is transferred to water changing it into steam, which is then either used to heat homes via central heating systems or to create power using a steam turbine. These boilers are mainly sold to power producers or to customers operating in the pulp and paper industry where they are needed for paper production. Fluidised bed boilers usually constitute just a small part of a plant. A rough flow diagram, Figure 6, provides an overview of what occurs in a plant. The picture illustrates the process from fuel delivery via fuel preparation and combustion through emission reduction measures to release in the air via the chimney. Moreover, both the water/steam cycle and the residue disposal are included.

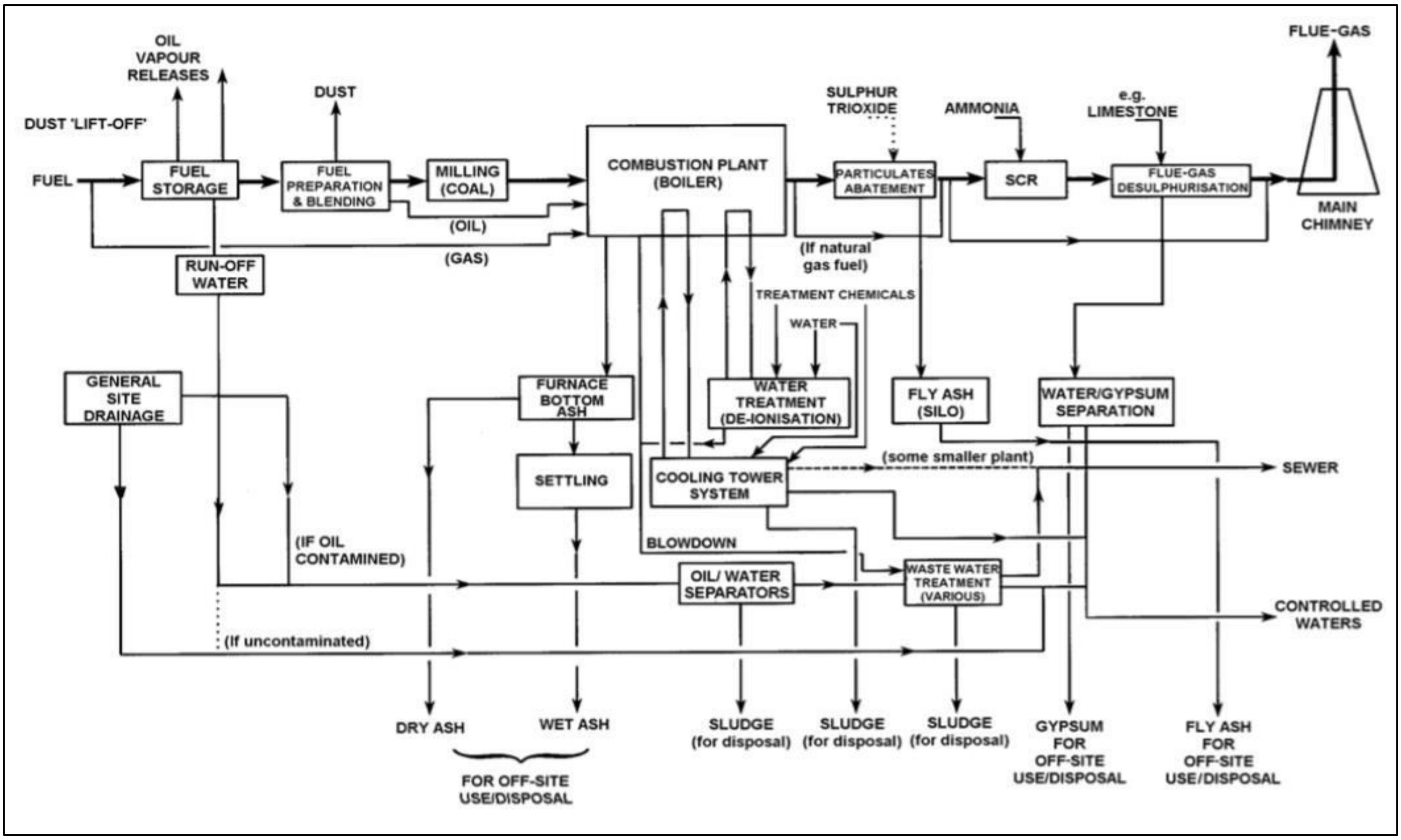


Figure 6: General flow diagram of a combustions plant and its associated operations [47]

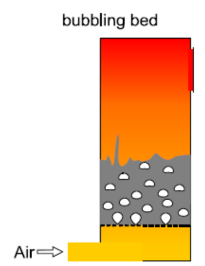
The technology of a fluidised bed boiler is a relatively new way of burning combustibles. This technology, in comparison to a grate fired boiler, does not carry the fuel on a grate but in a hot

[46] Cf. MENTHE, T.; SIEG, M. (2013), p. 125.
[47] LECOMTE, T. et al. (2017), p. 16.

sand bed which is fluidised by nozzles pumping air through the bed from underneath.[48] Furthermore, fluidised bed boilers can be divided according to the state of the bed material relative to the nozzles, into bubbling and circulating fluidised bed boilers.

2.3.1 Bubbling fluidised bed boilers (BFB)

Bubbling fluidised bed boilers are characterised by a stationary bed. This means that the bed material is fluidised by air and the entire bed material remains at the same height above the nozzles (see Figure 7).



With increasing air flow, the fixed bed expands to form a bubbling bed of ascending and bursting bubbles of air.

Fluidising velocity ~ 1 m/s

Figure 7: Principle of a BFB boiler and its fluidisation velocity[49]

Andritz AG sells different configurations of bubbling fluidised bed boilers depending on the fuel to be incinerated and the output performance of the boiler. Table 9 shows the three different concepts according to the combustibles.

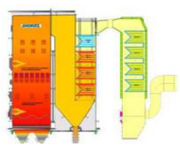
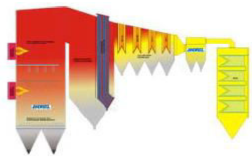
	ECOFLUID “BC“ Biomass concept 	**ECOFLUID “AC“ Advanced concept** 	**ECOFLUID “RC“ Residue concept** 
Fuels	Wood, bark, peat (clean biomass)	Biomass, sludge, waste wood, rejects, agricultural residues	RDF, rejects, sludge

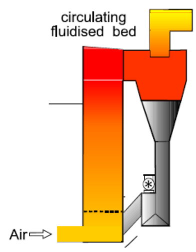
Table 9: Different concepts of BFB boilers offered by ANDRITZ AG[50]

2.3.2 Circulating fluidised bed boilers (CFB)

In circulating fluidised bed boilers, the pressure of the nozzles is so high that the bed is swirled through the whole burning chamber. In order to prevent the bed material from being exhausted with the flue gas a vortex finder is installed. The task of this equipment is to separate the

[48] Cf. https://www.carmwen-ev.de (07.01.2018)
[49] Cf. ANDRITZ AG internal data
[50] Cf. ANDRITZ AG internal data

swirling bed material from the flue gas. The separated bed material then flows through a cyclone, where it is led back into the burning chamber via a siphon (see Figure 8).



With further increase the point of loosening and the transition phase to pneumatic transport are reached and a circulating bed arises

Fluidising velocity ~ 5 m/s

Figure 8: Concept and fluidisation velocity of CFB boilers[51]

Compared to the bubbling bed the circulating bed boiler has a higher power density but is also technically more challenging and space demanding. ANDRITZ AG also offers a variety of circulating bed boilers, differentiated by the fuel burnt and the performance of the plant, as shown in Table 10.

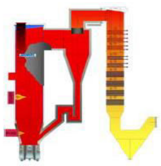
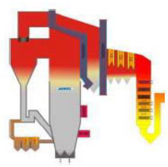
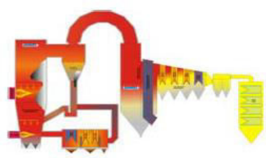
	POWERFLUID "CC" conventional concept 	**POWERFLUID "HC" hybrid concept** 	**POWERFLUID "RC" residue concept** 
Fuels	Coal, clean biomass, sludge, petcock	Waste wood, RDF, rejects, sludge, coal	RDF, rejects, sludge, waste wood, coal

Table 10: Different concepts of CFB boilers sold by ANDRITZ AG[52]

The CFB and the BFB systems require different fluidisation velocities pictured in Diagram 2. Clearly the CFB concept needs a higher velocity because the bed material is swirled through the whole burning chamber, thus requiring more energy. One important fact that can easily be seen in Diagram 2 is that a BFB boiler produces no pressure loss once it is fluidised, making it more efficient.

[51] Cf. ANDRITZ AG internal data
[52] Cf. ANDRITZ AG internal data

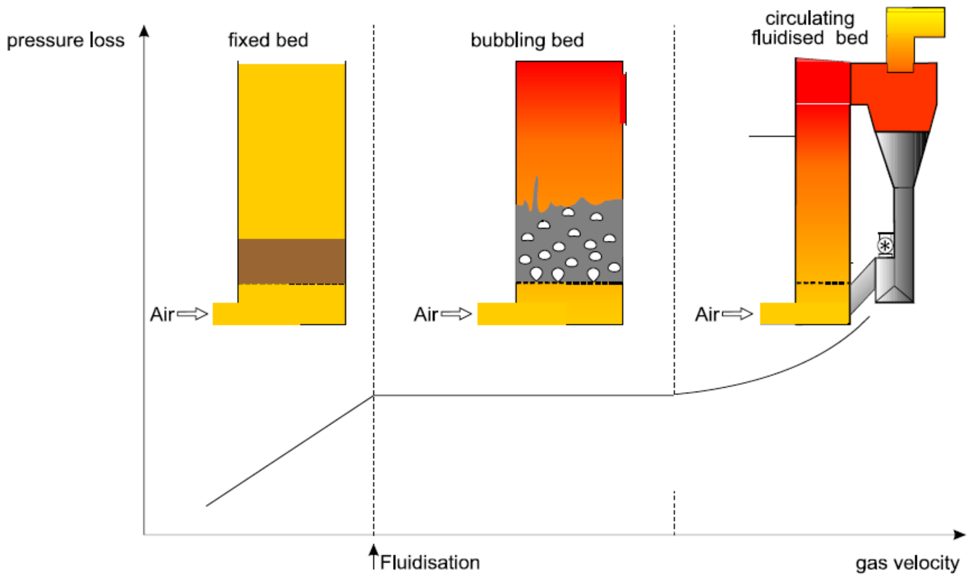


Diagram 2: Pressure loss related to the gas velocity of different boiler types[53]

The technique of fluidising the bed has a lot of advantages:

- Extreme fuel flexibility: firing various fuels (RDF, rejects, waste wood, sludge) and fossil fuels (coal, fuel oil, natural gas) in one boiler;
- Intense turbulences in the combustion reaction zone: excellent destruction of organic and toxic components;
- Superb burn-out rate: minimum CO and TOC flue gas emissions, minimum unburnt content in as;
- Low combustion temperature: no thermal NOx generation;
- Primary desulphurization by dosing limestone into the furnace: economic SOx reduction in downstream FGC plant;
- Low excess air for combustion reaction: beneficial to the design of FGC and fans;
- Compliance with waste incineration directive 2000/76/EC. (Especially flue gas temperature > 850°C for minimum 2 seconds).[54]

As no system is error-free some disadvantages exist:

- A high gas throughput and small solid matter grain size lead to a high solid matter discharge → danger of erosion and particle breakage;
- Solid matter that runs through softening points when heating up to reaction temperature tends to be sintering;
- The spectrum of particle size of the solid matter needs to be within a certain range to prevent rainfall;
- A reverse flow of gas and solid matter is only achievable with a multi-stage arrangement;

[53] Cf. ANDRITZ AG internal data
[54] Cf. ANDRITZ AG internal data

- Poor radial gas mixing and a bypass of swirl gas by bubbles leads to a broad dwell-time distribution of the face gas;
- Fluidized bed reactors are hard to enlarge to big operational scales;
- Back mixing of gas through porous solid matter can impair the reaction turnover.[55]

2.3.3 Bed material

The bed material used for both the CFB and the BFB concept consists of ash and additives. It is essential for fluidised bed boilers due to the tasks it fulfils. It:

- guarantees sufficient oxygen concentration over the layer height;
- intensifies the heat exchange and the decrease in the incineration temperature;
- stores heat to stabilize combustion at low temperatures.[56]

2.4 Emissions of Large Combustion Plants

The supply of electricity for private and/or business consumers is an important drive for economic growth and is therefore a reason why more and more combustion plants are being constructed. However, with an increasing number of plants and an increasing need for energy more combustibles are being burnt and consequently more harmful molecules emitted. Since zero incineration is ideal, the combustion of natural resources or waste has a huge environmental impact whereby emissions pollute the air, water and soil. However, the majority of the pollution generated by large combustion plants is emitted to air. Consequently, this chapter is limited to such emissions.

2.4.1 Best Available Techniques Reference Document (BREF)

To regulate the environmental impact, the European parliament and the council of the European Union introduced a directive on industrial emissions. By using the directive 2010/75/EU a Best Available Techniques Reference Document (BREF) for large combustion plants was derived. This document represents a conclusion of limitations for all types of emissions depending on the size of the plant. The BREF consists of: "*information on a specific industrial/agricultural sector in the EU, on the techniques and processes used in this sector, current emission and consumption levels, techniques to consider in the determination of the best available techniques (BAT) and emerging techniques.*"[57] Meeting these limitations will be compulsory for every combustion plant in Europe from a defined date.

The BAT conclusion has been established through an iterative process involving the following steps:

1. identifying the key environmental hazards;
2. examining the techniques most relevant for reducing these key issues;

[55] Cf. ANDRITZ AG internal data
[56] Cf. ANDRITZ AG internal data
[57] http://eippcb.jrc.ec.europa.eu (05.12.2017)

3. identifying optimum pollution levels;
4. examining the conditions under which these pollution levels were achieved, such as costs, cross-media effects, and the main driving forces involved in the implementation of the techniques;
5. selecting the best available techniques (BAT), their associated pollution levels and the associated monitoring for this sector according to Article 3(10) of, and Annex III to, the Directive.[58]

"Within Annex III to the directive the criteria for determining best available techniques are listed:

1. the use of low-waste technology;
2. the use of less hazardous substances;
3. the furthering of recovery and recycling of substances generated and used in the process, and of waste, where appropriate;
4. comparable processes, facilities or methods of operation which have been tried with success on an industrial scale;
5. technological advances and changes in scientific knowledge and understanding;
6. the nature, effects and volume of the emissions concerned;
7. the commissioning dates for new or existing installations;
8. the length of time needed to introduce the best available technique;
9. the consumption and nature of raw materials (including water) used in the process and energy efficiency;
10. the need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to it;
11. the need to prevent accidents and to minimise the consequences for the environment;
12. information published by public international organisations"[59]

2.4.2 Emissions to air

According to the latest BREF document the most important emissions to air are SO2, NOX, CO, particulate matter (dust) and greenhouse gases, such as CO2. Furthermore, substances, such as heavy metals, hydrogen fluoride, hydrogen chloride, unburnt hydrocarbons, non-methane volatile organic compounds (NMVOCs) and dioxins are emitted.[60]

2.4.2.1 Sulphur oxides

Sulphur emissions are mainly attributable to a sulphuric fuel. The majority of sulphur oxides are present as sulphur dioxide but about 5 % of the total sulphur emitted can arise as SO3 in plants with inbuilt SCR (selective catalytic reduction).[61]

SO_x/SO_2 emissions to air are illustrated in Figure 9. The severity of these pollution emissions by large combustion plants and the necessity of reduction is clearly apparent.

[58] Cf. LECOMTE, T. et al. (2017), p. i.
[59] Annex III to directive 2010/75/EU, p. 57.
[60] Cf. LECOMTE, T. et al. (2017), p. 18.
[61] Cf. LECOMTE, T. et al. (2017), p. 19.

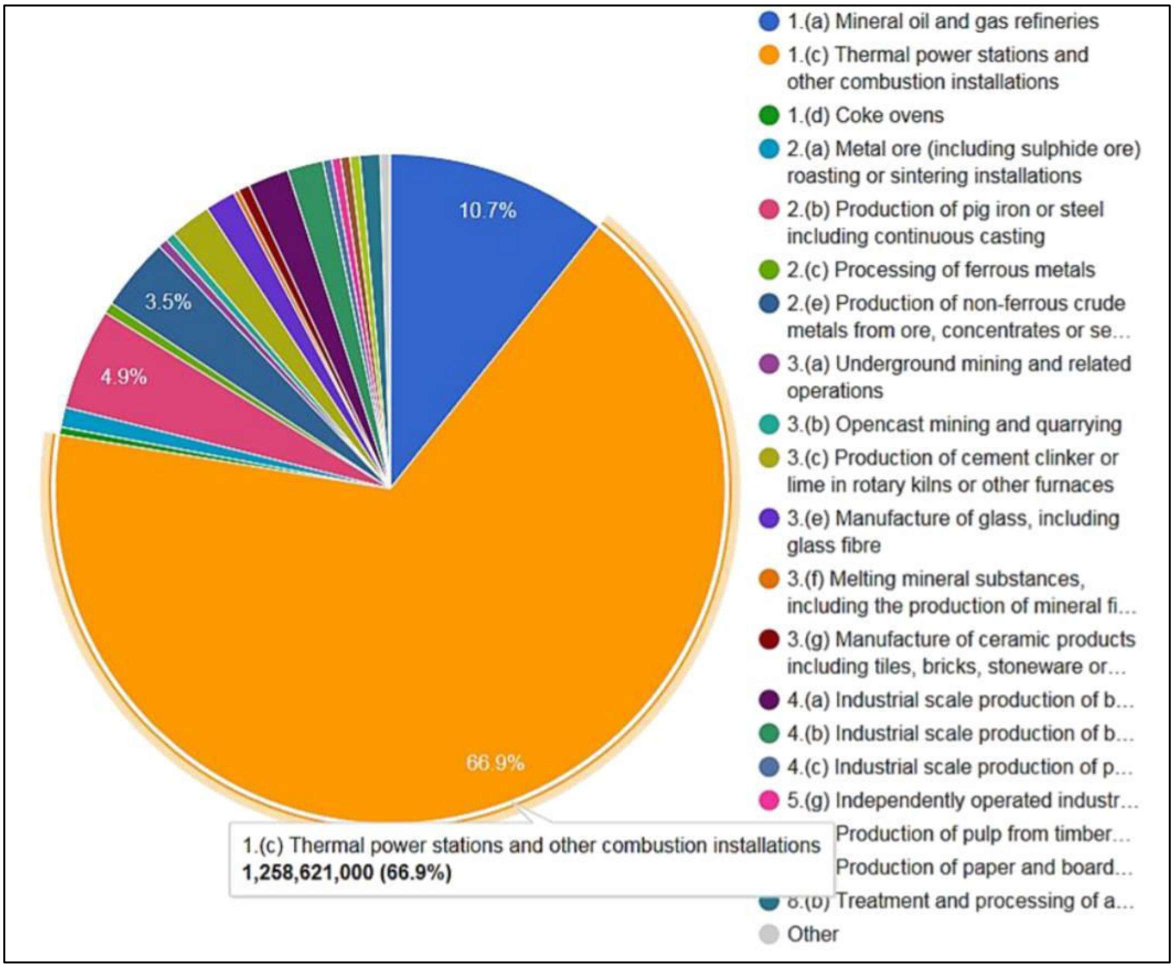


Figure 9: Emissions of SO_x/SO_2 to air by industry sector/activity in the EU-28 in 2014[62]

2.4.2.2 Nitrogen oxides

Nitrogen oxides, also known as NOX, are generated when burning fossil fuels. Three different molecules can be created, nitric oxide NO, nitrogen dioxide (NO_2) and nitrous oxide (N_2O), whereas only the nitric oxide and the nitrogen dioxides are named NOX and are the main nitrogen pollutants.[63]

The formation of NOX is performed by three essential mechanisms and is categorized according to the source occurrence:

- thermal NOX results from the reaction of oxygen and nitrogen from air;
- fuel NOX is formed by nitrogen contained in the fuel;
- prompt NOX arises from the conversion of molecular nitrogen in the flame front, in the presence of intermediate hydrocarbon compounds.[64]

NOX/NO2 emissions to air with special reference to the industry sector of ANDRITZ AGs Pulp and Paper division are illustrated in Figure 10.[65]

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[62] LECOMTE, T. et al. (2017), p. 20.
[63] Cf. LECOMTE, T. et al. (2017), p. 20.
[64] Cf. LECOMTE, T. et al. (2017), p. 21.
[65] Cf. LECOMTE, T. et al. (2017), p. 22.

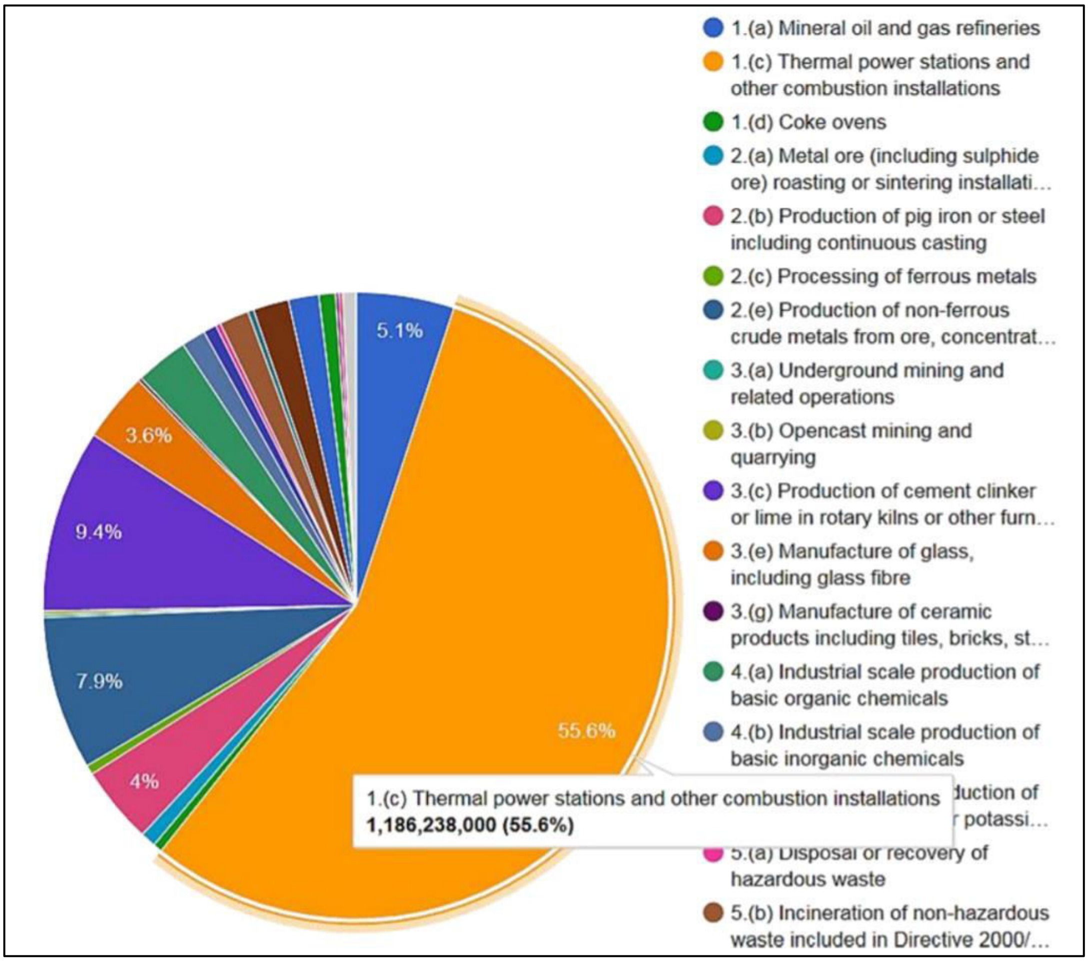

Figure 10: “Emissions of NO_x/NO_2 to air by industry sector/activity in the EU-28 in 2014”[66]

2.4.2.3 Dust

The dust emitted by the combustion of biomass, peat or coal comes from the mineral fraction of the fuel. A small part of the dust contains unburnt fuel carbon and very small particles created by the condensation of compounds vaporized during combustion. On the other hand, the combustion of natural gas is not a significant source of dust emissions due to the absence of solid particles.[67]

The smaller the diameter of the particles, the bigger the health impact. The threshold for harmfulness lies at about 2.5 µm. Smaller particles may stay days or even weeks in the atmosphere before settling and can thus easily travel hundreds of kilometres. Larger particles mostly effect the immediate surroundings of the source before settling. Industrial emission control techniques for particulate matter (PM) are very efficient, achieving more than 99.8 % by weight removal from the raw gas input.[68]

[66] LECOMTE, T. et al. (2017), p. 22.
[67] Cf. LECOMTE, T. et al. (2017), p. 23.
[68] Cf. LECOMTE, T. et al. (2017), p. 23.

For small particles such as PM10 and those below, does removal efficiency decrease to between 95 % and 98 %. This is the reason why, the majority of particles from LCPs still emitted to the air are in a 0.1 µm to 10 µm diameter range.[69]

PM10 emissions to air are shown in Figure 11 with special reference to the industry sector in which ANDRITZ AGs Pulp and Paper division operates.

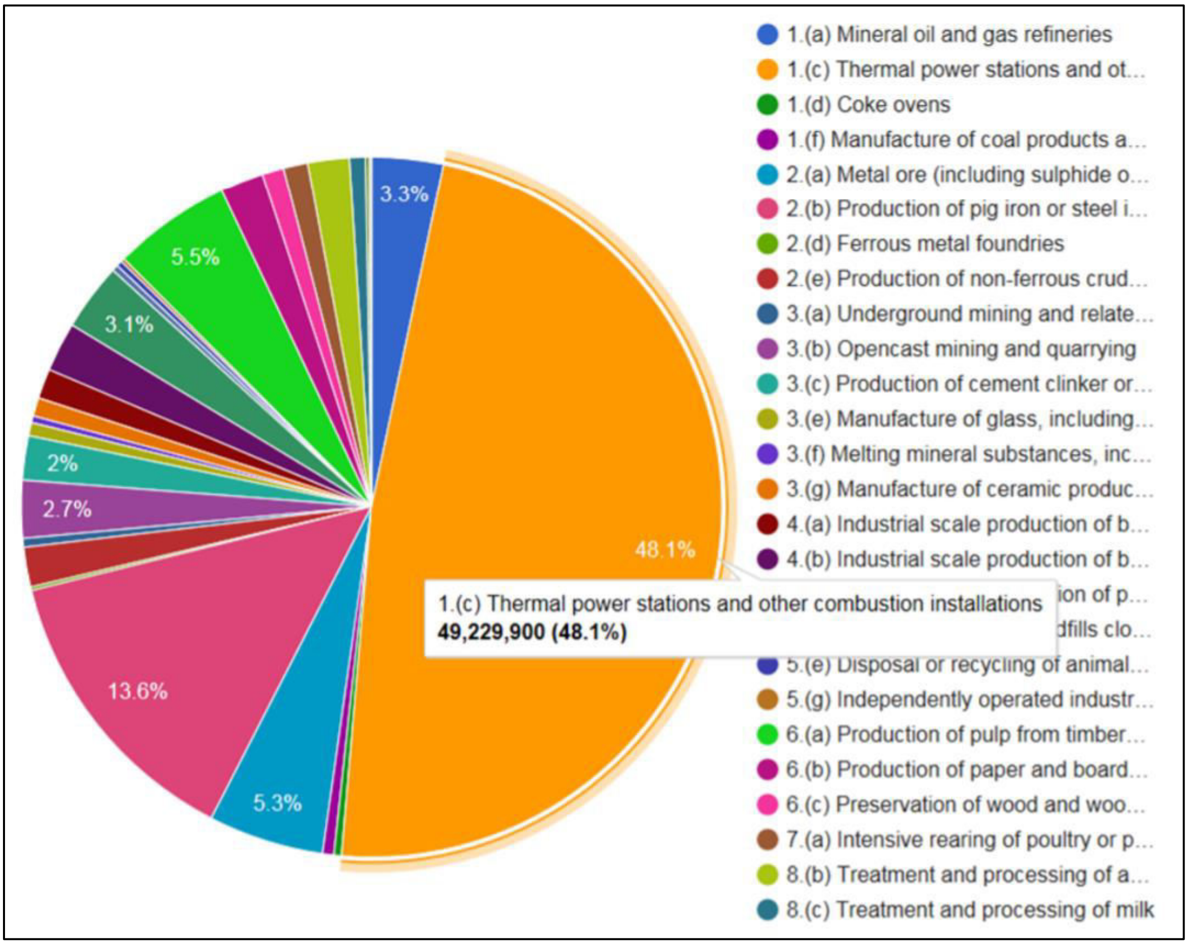

Figure 11: Emissions of PM_{10} to air by industry sector/activity in the EU-28 in 2014[70]

2.4.2.4 Combustion residues

The combustion of fuels is associated with the generation of a variety of residues (waste and/or by-products). Substances or objects resulting from a production process, the primary aim of which is not the production of that item, may not be regarded as waste but as by-products provided the proper requirements for them to be sold on the market are met (e.g. fly ash, gypsum from flue gas desulphurisation). According to their origin, residues from a combustion plant can be divided into those directly related to the process of combustion, or those generated by the operation of the plant and its equipment, such as coal mills or water treatment facilities. Residues directly related to the combustion of fuels are ashes (fly and bottom ash) and residues that are generated by the desulphurisation of flue gases.[71]

[69] Cf. LECOMTE, T. et al. (2017), p. 23.
[70] LECOMTE, T. et al. (2017), p. 24.
[71] Cf. LECOMTE, T. et al. (2017), p. 36.

The main residues generated by LCPs are as follows:[72]

- **Bottom ash and/or boiler slag:** Bottom ash is a material that collects at the bottom of the boiler and remains in the form of non-agglomerated ash. When the combustion temperature exceeds the ash fusion temperature, the ash remains as molten slag until it is extracted from the boiler bed.

- **Fluidised bed ash:** The operation of a fluidised bed combustion installation with a solid fuel generates ash, which is composed of spent bed material and fuel ash. Bed ash is extracted from the bottom of the fluidised bed combustion chamber and is ideally 60 kg/(h*MW).

- **Fly ash:** Fly ash represents that part of the ash generated which is carried out of the boiler along with the flue gas. The remainder stays in the boiler chamber as fluidised bed ash or short bed ash. Fly ash is reduced by particulate matter control equipment, such as the electrostatic precipitator or bag house filter.

- **Flue gas desulphurisation residues:** Fuels such as coal, peat and oil contain sulphur. To avoid high emissions of sulphur dioxide to the atmosphere, flue-gas desulphurisation (FGD) systems are usually installed. The desulphurisation of flue gas forms many different residues.

Wet lime/limestone scrubbers, for example, generate gypsum as a by-product, whereas dry scrubber systems create a mixture of unreacted sorbent (e.g. lime, limestone, sodium carbonates and calcium carbonates), sulphur salts and fly ash. After being extracted from the plant, these residues may be disposed of in a landfill or can be used as by-products for different purposes:

- in cement and concrete production;
- as an aggregate in concrete and asphalt;
- for mine reclamation or waste stabilisation and
- as an ingredient in many other products.[73]

[72] Cf. LECOMTE, T. et al. (2017), p. 36.
[73] Cf. LECOMTE, T. et al. (2017), p. 36.

3 Practical Problem Solving

This chapter comprises two major fields which will be examined in greater detail. The first and more expansive topic explains how to create a value a customer can understand and comprehend as simply as possible. The focus lies on the ‘value for the customer’ as described in the theory section in 2.1. For ANDRITZ AG the values derived will be used for sales planning and the sales talk itself. The values represent an excellent basis for sales arguments that can be perfectly adapted to the customer in question, thereby promising higher revenues and more customers.

In addition, the well-known field of emissions regulations will be explained in the following pages. This is a trending topic nowadays as nearly every country is trying to reduce their greenhouse gas emissions. Here the degree of reduction of certain pollutants and the measures needed to meet the standards will be discussed. ANDRITZ AG is attempting to use the emissions regulation reform, which will come into effect in 2020, in its approach to its customers. As this master thesis is intended to create a basis for the sales division, discussion of the topic is highly significant. It should help sell a greater volume of products and bind the customer to the company. Unfortunately, the reduction of emissions pollution cannot be used for the ‘value for the customer’ calculation. However, it is still an effective way to approach customers and remind them to undertake modifications in accordance with the new regulations. It is hoped that the customer will then purchase the measures required to meet the emissions standards at ANDRITZ AG.

3.1 Definition of the Problem

ANDRITZ AG has a deficit in its marketing strategy for the sale of service products within the PKP Kraft and Paper Mill Service division, this being a relatively new field for them. According to the product group *service products*, the problem was that in the past the approach of Andritz AG to selling products was to react to public tendering. The disadvantage of this strategy is that a large number of competitors respond to the same tendering simultaneously resulting in increased competition.

The difficulty for Andritz AG in maintaining its market position is that it cannot be the cheapest provider due to the strong competition of Chinese and Japanese companies, but also due to that of European pulp and paper giants who make it hard to survive. Customers usually prefer the cheapest solution which is generally the eastern version. Therefore, it is essential that the corporation scores by virtue of the high quality and value of its products. Hence, Andritz AG has been confronted by new problems which should now be solved.

As a means to overcoming this obstacle ANDRITZ AG offered this master thesis which aims to improve the sales division. More precisely, this scientific research should conclude by providing a proper Excel sheet listing all the benefits of the entire product range. The customer values calculated act as ‘munition’ for the salesmen. Neither the marketing nor the sales divisions are used to the new type of products since services have only been sold for a short time. This means the department cannot boast any expertise drawn from experience nor any real selling arguments, largely because the sales department knows little about the new approach ANDRITZ AG has just implemented. This is the barrier that needs to be overcome by this master thesis. The use of service products is a new way of approaching customers, or rather the new way is approaching the customer and no longer waiting until the customer approaches the company. The customers should have a close, intense relationship to ANDRITZ AG, and it is hoped this will be a positive one in order to increase the volume of repurchases.

However, creating arguments and translating them into monetary values is just one aspect of a sales improvement.

3.2 The Service Packages of Andritz AG

The service packages of Andritz AG consist of different services including start-up support, shutdown planning and many more as shown in Table 11 below. Three different packages exist that vary in the number of services and costs of the package. The cheapest package is the Inspection Package which only includes an inspection and report of the pressure parts and fluidized bed module together with a 2-day advisory service.

The medium version is the 'Inspection^{plus}' package where all critical parts are included in the inspection and report service and an operations review is added. Furthermore, the advisory service increases to 4 days. This package is the most likely service version to be purchased because of the huge increase in services provided compared to the cheaper Inspection package and the relatively similar offer as opposed to the 'Performance' package.

The most expensive and therefore high-end solution is the performance package. In contrast to the 'Inspection^{plus}' package general shutdown planning and start-up support are also sold within this package. The service products are used solely for maintaining existing plants and can be purchased with a whole fluidised bed plant, but also as an addition later on. Depending on the product, the price and the services vary. Each product is sold on a yearly basis ranging from 30,000 – 80,000 euros annually. Initially only the service products which were introduced later were included in the added value calculation, but subsequently the rest of the 'Replacement^{plus}' products of Andritz AG were taken into consideration, whereby new calculations had to be performed to be able to identify all the advantages involved.

	Power Service Inspection package	Power Service Inspection^{plus} package	Power Service Performance package
Inspection + report			
Pressure parts	X	X	X
Wall thickness meas.		X	X
Fuel handling system		X	X
Ash handling system		X	X
Fluidized bed module	X	X	X
Air system		X	X
Operations review		X	X
Advisory services (extra days at daily rates)	2 d	4 d	4 d
General shutdown planning			X
Start-up support			X

Table 11: Power service packages – tasks included[74]

3.3 Value for the Customer – ANDRITZ AG

As described in the theoretical section of this paper, the term 'value for the customer' is understood as a rating of value from the customer perspective in monetary units. The aim was to show the customer how much value the products of Andritz AG will create for them. The value gained is expressed in monetary units to promote comprehensibility. This is a rather new approach for ANDRITZ AG to attract customers, therefore only the service products offered were considered initially. Later on, the calculations were extended to a certain amount of 'Replacement^{plus}' products which are already on the market. Hence, the aim of this chapter is to create a basis for the sales force since no real sales arguments exist for this division. A large number of product benefits were collected and later translated into a monetary value.

[74] Cf. ANDRITZ AG internal data

3.4 How the 'Customer Benefits' were Derived

Defining advantages that are very important and money saving from the perspective of the customer was essential. The result was a first list of benefits. The table below includes all replacement and service products of the Andritz AG pulp and paper power plant service division. Few products were deleted, based on a flyer the company published, to describe exactly the products comprised in this flyer.

product group	Product	Investment costs [k€]	Benefits
service packages	Inspection package	40	Ability to act when needed, future expenses can be better estimated
	Inspection^{plus} package	80	Ability to act when needed, future expenses can be better estimated, less money lost due to reduced shutdown period, reduced unscheduled shutdowns
	Performance package	200	Maximum efficiency and availability realised, future expenses can be better estimated, review of the system data by an expert for better forecasting, less money lost due to reduced shutdown period, reduced unscheduled shutdowns
24/7 services	24/7 Services Norrkoping SE	50 - 100 k€/d	Higher availability due to faster possibility of service, reduced downtime
	24/7 Services Varkaus FI	51 - 100 k€/d	Higher availability due to faster possibility of service, lower downtime, flexibility in the event of tube leakages
Replacement^{plus} products	Spare & Wear parts	0,01 - 100	High quality directly from the OEM
	Superheater for standard fuels	200 - 1000	Resistance against corrosion/erosion, perfectly adapted to its intended purpose
	Superheater for waste fuels	200 - 1000	Higher chlorine content, higher resistance against corrosion/erosion caused by aggressive fuels
	Superheater RC^{plus}	100 - 1000	Less plugging, less pressure loss on flue gas side, improved heat transfer and therefore greater efficiency
	Superheater f. bed material cooler	300 - 500	Lower investment costs, shorter erection time
	Membrane wall panels	50 - 200	Faster erection time, higher chlorine content possible
	Additional CC heat surfaces	1000 - 2000	Lower combustion chamber outlet temperature, resulting in lower flue gas velocity, therefore higher load or fuel with lower heating value possible
	Economiser	100 - 1000	Resistance to cold end corrosion and erosion, optimized heat surface alignment

product group	Product	Investment costs [k€]	Benefits
	Heat surface protection	1 - 100	Improved lifetime and therefore longer availability
	BFB nozzle grid for standard fuels	200 - 500	Less shutdown time, less lambda, less flue gas amount, higher load possible, less power for ID fan (all data in comparison to closed nozzle grid)
	BFB nozzle grid for waste fuels	200 - 500	In addition to standard open nozzle grid more and larger impurities in the fuel are possible
	CFB nozzle grid for standard fuels	200 - 800	Less shutdown time, less lambda, less flue gas amount, higher load possible, less power for ID fan (all data in comparison to closed nozzle grid)
	CFB nozzle grid for waste fuels	200 - 800	In addition to standard open nozzle grid more and larger impurities in the fuel are possible
	CC cross-over tube protection	100 - 200	Less erosion at membrane wall, no adaption of pressure part necessary
	Vortex finder	100 - 400	Less carry over leads to less erosion at convective heat surfaces, longer lifetime
	Pneumatic fuel feeding systems	300 - 800	Less carry over of light fuels, higher and more stable bed temperature, better combustion, wider scope of fuels
	Advances fuel control	100 - 200	Higher stable load with cheaper fuels, stable heat production, more stable emissions
	Advances bed material recirculation	100 - 300	Less fresh sand consumption, less agglomeration of bed material and therefore less plugging
	Advanced corrosion reduction	400 - 600	Higher chlorine content in fuel, cheaper fuel, fewer chlorine-induced errors (e.g. superheater)
	Advanced SNCR systems	250 - 500	Perfectly adapted to boiler, reduced NOx emission
	Advanced hybrid SNCR systems	300 - 600	Very low NOx emissions possible, low investment for erection, low pressure loss, no tail-end SCR necessary
upgrades	Upgrade 1st step: Concept development	20 - 30	Solution approach by an expert
	Upgrade 2nd step: Feasibility study	50 - 100	Quotation of desired solution and feasibility study
	Upgrade 3rd step: Realisation	2000 - 5000	Realisation of the solution

Table 12 (extension): First table of benefits modified with the rough investment for each product[75]

The next step was a rough estimation of expenses needed to purchase the products. To prevent repetition, the column for investment is already added in Table 12.

[75] Cf. ANDRITZ AG internal data

Using this information, one approach was to calculate a replacement investment scheme. The concept was that if a plant is modified, the service life of other boiler parts will increase. Unfortunately, the replacement investment calculation could only be used for the vortex finder, which is described later. The reason for this is that the effect on the service life could only be derived for the vortex finder because a slightly different composition of fuel burnt can cause deviations of the service life; further environmental circumstances can alter the lifetime even if it is the same plant type. However, this approach was also rejected due to the comparatively small impact of other products on the service life. Here the vortex finder is an exception because the service life enhancement was derived from the reduced erosion.

The second attempt was a calculation of the running costs of a plant subtracting the income of the whole plant. The thinking behind the concept was that if a change was made all the costs would have been reduced and would therefore generate a higher revenue at the end; this is then equivalent to the customer benefit created by an adjustment. The problem of this experiment was that Andritz AG does not possess detailed information about existing plants.

The same conclusion resulted from an extension of Table 12 above, where the columns duration of reconstruction, service life, number and duration of planned and unplanned shutdowns were added to allocate the data to a product, but none of this data could be collected. Only the quantity of steam produced and the type of fuel is known.

After a long literature research and in consideration of the restrictions a new table was created using the first table of benefits. The schema, pictured in Table 13, was taken from the literature and was then adapted to meet our requirements.

<table>
<tr><th rowspan="2">product</th><th rowspan="2">Product Parts</th><th rowspan="2">Advantage</th><th rowspan="2">Customer Benefit</th><th colspan="3">Category & Relevance</th><th rowspan="2">Motive</th><th rowspan="2">Customer Benefit [€]</th></tr>
<tr><th>m</th><th>c</th><th>d</th></tr>
<tr><td rowspan="4">Inspection package</td><td rowspan="3">Inspection + report of pressure parts
Inspection + report of fluidized bed module</td><td>Actual status of mechanical equipment</td><td>Fewer unexpected shutdowns/ better budgeting => lower maintenance and personnel costs</td><td>3</td><td></td><td></td><td>Cost saving due to reduction of unplanned SD, purchasing success due to planning reliability</td><td>Unpl. SD-day (50-100 kE); purchasing suc. -10% of order costs (20-40 kE)</td></tr>
<tr><td>Information on existing or future weaknesses or failures</td><td>Better budgeting => lower maintenance costs</td><td>3</td><td></td><td></td><td>Purchasing success due to planning reliability</td><td>Purchasing suc. -10% of order costs (20-40 kE)</td></tr>
<tr><td>External inspections by professionals</td><td>Higher quality of information about the plant</td><td></td><td></td><td>2</td><td>Professional support/opinion</td><td>-</td></tr>
<tr><td>2 days' advisory service (extra days at daily rate)</td><td>Doing the right things in the right way!</td><td>Lower maintenance costs</td><td></td><td></td><td>1</td><td>Cost saving/ plant reliability</td><td>Reduction of maintenance costs</td></tr>
</table>

Table 13: Table of values for the customer of the 'Inspection' package

Table 13 shows the first draft of the concept. In the first column the name of the product is written. The second column represents the product parts included in a certain service package but is not needed for the rest of the 'Replacement^{plus}'. In the first version, shown above, the columns category and relevance are included. The task of the category is to define whether a benefit is calculable, measurable or decidable. The relevance should weigh the benefit according to the priority for the customer. The column motive represents the motive a customer has to buy the product. It is the reduction of the benefits to its elemental parts, which can then be easily translated into the benefit expressed in euros stated in the far right column. The customer benefit in euros is the most important part of the table because it constitutes the basis for the calculations described later.

The second version was then reduced because there was no need for a relevance. On the one hand, there was no time for a customer survey, and on the other all benefits are almost equally important especially within the B2B area. Furthermore, the categories were reduced to qualitative and quantitative because a distinction between calculable and non-calculable was sufficient.

product	Product Parts	Advantages	Customer Benefit	Catego-ries		Motive	Customer Benefit [€]
				quantitative	qualitative		
Inspection Package	Inspection + report of pressure parts Inspection + report of fluidised bed module	Actual status of mechanical equipment	Fewer unexpected shutdowns/ better budgeting => lower maintenance and personnel costs	✓		Cost saving due to reduction of unplanned SD, purchasing success due to planning reliability	**Unpl. SD-day (50-100 kE); purchasing suc. -10% of order costs (20-40 kE)**
		Information on existing or future weaknesses or failures	Better budgeting => lower maintenance costs	✓		Purchasing success due to planning reliability	**Purchas-ing suc. -10% of order costs (20-40 kE)**
		External inspections by professionals	Higher quality of information about the plant		✓	Profession-al support/ opinion	**-**
	2 days' advisory service (extra days at daily rate)	Doing the right things in the right way!	Lower maintenance costs	✓		Cost saving/ plant reliability	**Reduction of main-tenance costs**

Table 14: Modified table of 'values for the customer' following T. Menthe

The schema of Table 14 was performed for all 'Replacement^{plus}' products included in a flyer created by ANDRITZ AG. After the table of benefits had been completed all products were calculated on a separate Excel sheet in order to increase comprehensibility.

It is necessary to mention that often the non-calculable values are the ones driving the purchasing decision because most of the time these benefits show the difference to the competitor. Therefore, the values of this category are mainly used for the customer discussion and require a good feeling of what the potential consumer wants. As already stated in the previous chapters, the salesman decides during the conversation which argument to present and which not, depending on how the salesman judges the customer.

The next step was to define the calculation for the quantitative values. After the values had been broken down into their elementary parts, for example, and a higher availability could be defined by a reduction of maintenance material and maintenance personnel, the time the maintenance personnel needs and a reduction of the duration of a planned or unplanned shutdown, the calculations had to be set up. How the benefits were calculated is described in detail in the next section.

3.5 The Translation of Benefits into Monetarised 'Customer Benefits'

The following sections provide an insight into how the calculations were derived and performed. The model uses simple cognitive algebra and is utilized for all products sold by Andritz's PKP Kraft and Paper Mill service division. Some savings had to be machined separately because the degree of complexity of the calculation and the amount of potential benefit was higher or could not be derived trivially.

For a better understanding of the issue the service packages in total, the sand consumption and the fuel usage are described as examples. The second is just one part of the whole customer value of the bed material recirculation. Lastly, the vortex finder calculation is depicted due to the fact that it is the only equipment which was calculated using the service life of the product and the equipment affected by it.

For every product calculated a type of conclusion sheet summing up all the customer benefits was created. The schema of these sheets is the same as described under *The translation* of *service packages* but may slightly differ for other products because of the variety of advantages derived in advance. Within the calculations only the background of the conclusion sheets is described due to the amount of space that would be required to depict every product considered. The complete data can be found in the Appendix containing every sheet created.

3.5.1 The translation of service packages in detail

The first thing to do was to create a table with constants. Every product has its own constants but some are the same independently of what part is calculated. Starting with the service packages, the task was to define the calculations needed for each added value on the list. As shown in **Error! Reference source not found** the product inspection package boasts a lot of benefits. Position 1 in **Error! Reference source not found** below says that you get the actual status of the mechanical equipment, which creates the value of less unexpected shutdowns because of better maintenance planning and further a better budgeting. If the duration or the number of unexpected shutdowns decreases, lower maintenance and personnel costs are the result.

product	Product Parts	Benefit	Value	Categories		Motive	Customer Benefit [€]
				quantitative	qualitative		
Inspection Package	Inspection + report of pressure parts Inspection + report of fluidised bed module	Actual status of mechanical equipment	Fewer unexpected shutdowns/ better budgeting => lower maintenance and personnel costs	✓		Cost saving due to reduction of unplanned SD, purchasing success due to planning reliability	**Unpl. SD-day (50-100 kE); purchasing suc. -10% of order costs (20-40 kE)**
		Information on existing or future weaknesses or failures	Better budgeting => lower maintenance costs	✓		Purchasing success due to planning reliability	**Purchasing suc. -10% of order costs (20-40 kE)**
		External inspections by professionals	Higher quality of information about the plant		✓	Professional support/opinion	**-**
	2 days' advisory service (extra days at daily rate)	Doing the right things in the right way!	Lower maintenance costs	✓		Cost saving/ plant reliability	**Reduction of maintenance costs**

Table 15: Modified table of 'values for the customer' for the 'Inspection' package

The difference between the two columns motif and customer benefit shown in Table 15 is that the motive is the reason for the customer to purchase and the added value is the motive expressed in variables needed to calculate the amount of it.

This schema is then transferred into an Excel sheet to be calculated as shown in the Appendix. Since ANDRITZ AG possesses only little information on existing plants built by competitors and even of plants built by ANDRITZ AG itself, this increases the difficulty of calculating the 'customer benefit'. The reason is that every plant is operated differently and consists of other modules. In addition, fuel varieties depending on the region also have to be taken into consideration. Thus, the calculations had to be broken down to a scope where the data available is sufficient. The data for the calculation comes extensively from the head of the department and co-workers, and was gathered over the years through experience. The lowest possible variables were chosen to be on the safe side so the calculations would be correct no matter what plant is the focus of the added value calculations. Within the Excel file the same kind of products has been collected in one Excel sheet calculation. All service packages are machined in one and the same sheet as shown in Appendix 6. Thus, four tables necessary for each calculation were created.

First is the size of the plant measured in MW_{th} or steam production per hour.

Boiler [MW_{th}]	90	MW_{th}
Steam production [t/h]	108	t/h

Table 16: Main variables to be entered for the calculation

The conversion rate from steam production per hour to thermal performance MW_{th} is determined empirically and is shown by Equation 1 below.

$$Thermal\ Performance = \frac{steam\ production\ per\ hour}{1.2}$$

Equation1: Conversion of steam production to thermal performance[54]

The second table consists of all the constants of a combustion plant such as operational time per year, average costs per ton of steam, the costs of a planned and unplanned shutdown day and many more characteristic constants.

Constant	Value	Unit
Average costs per ton of steam	30	€/t
Operational time per year	8000	h
Average boiler efficiency	90%	
Estimated costs of a planned shutdown day of the boiler	40000	€/d
Estimated costs of an unplanned shutdown day of the boiler	50000	€/d
Estimated personnel costs of maintenance work during planned shutdown	310000	€
Estimated costs of spare and wear parts during shutdown	160000	€
Workforce needed for planned shutdown	15	pers.
Workforce needed for unplanned shutdown	4	pers.
Duration of planned shutdown	10	d
Working hours per shutdown day	20	h
Hourly rate (welder, fitter)	50	€/h

Table 17: Constants necessary for the 'value for the customer' calculation

The third table is the most important because it consists of the actual achievable improvement of different predefined parameters. The values included in Table 18 are all derived from experience with the help of supervisor Dr. Ulrich Hohenwarter.

Expected Potential of Improvements due to Service Packages	**Inspection Package**	**Inspection^{plus} Package**	**Performance Package**
Reduction of planned shutdown days [d]	0.5	2	4
Reduction of unplanned shutdown days [d]	0.5	1	1
Reduction of maintenance material [%]	5%	10%	10%
Improvement of efficiency [%]	-	-	0.2%
Purchase success for maintenance material due to timely ordering [%]	5%	10%	10%

Table 18: Actual reductions

The fourth table consists of the real added value expressed in monetary units. Most of the results entered in Table 19 below are simple multiplications that can be determined using the following equation:

$$
\begin{aligned}
&value\ of\ reduction\ of\ unplanned\ shutdown\ days\ [€] \\
&\qquad = estimated\ costs\ of\ unplanned\ shutdown\ day\ [€/d] \\
&\qquad * reduction\ of\ unplanned\ shutdown\ days\ [d]
\end{aligned}
$$

Equation 2: Savings due to a decrease of unplanned shutdown days

The same formula applies to the reduction of planned shutdown days as well as to the reduction of maintenance material and the purchase success for maintenance material due to timely ordering. The second is illustrated below.

$$
\begin{aligned}
&value\ of\ reduction\ of\ maintenance\ material\ [€] \\
&\qquad = estimated\ costs\ of\ spare\ \&\ ware\ parts\ during\ a\ shutdown\ [€] \\
&\qquad * reduction\ of\ maintenance\ material\ [\%] * 100
\end{aligned}
$$

Equation 3: Savings due to a decrease of planned shutdown days

For the purchase success, the equation would be:

$$
\begin{aligned}
&value\ of\ purchase\ success\ for\ maintenance\ material\ [€] \\
&\qquad = estimated\ costs\ of\ spare\ and\ ware\ parts\ during\ a\ shutdown [€] \\
&\qquad * purchase\ success\ for\ maintenance\ material\ [\%] * 100
\end{aligned}
$$

Equation 4: Value of the purchasing success due to better planning

In the case of a performance increase, the calculation is no longer trivially solvable. Thus the equation below explains how it was machined:

$$value\ of\ efficiency\ improvement[€] = \left(\left(1 + \frac{efficiency\ improvement[\%]}{average\ boiler\ efficiency[\%]}\right) * 100 - 1\right) * average\ costs/ton\ steam\ \left[\frac{€}{t}\right] * operational\ time/year\ \left[\frac{h}{y}\right] * steam\ production\ \left[\frac{t}{h}\right]$$

Equation 5: Monetary valuation of efficiency improvement

The calculation of the reduction of working hours by maintenance personnel can be described as a combination of the reduction of unplanned and planned shutdown days. The reason is that the reduction of planned and unplanned shutdown days only refers to forgone turnover, whereas the reduction of working hours by maintenance material is derived from the number of days the staff work less because of a reduction of shutdown days. To show how the calculation has been implemented, the formula is given below.

$$value\ of\ reduction\ of\ working\ hours\ of\ maintenance\ personnel = (reduction\ of\ planned\ shutdown\ days * workforce\ needed\ for\ planned\ shutdown + reduction\ of\ unplanned\ shutdown\ days * workforce\ needed\ for\ unplanned\ shutdown)$$

Equation 6: Monetary valuation of a reduction of maintenance hours

The results were then entered into the table of monetary values. All rows were added to establish the savings per year. After subtracting the costs of a certain product, in this case the service packages, the final and real monetary added value is generated.

Expected Potential of Improvements due to Service Packages for Selected Boiler [€]	Inspection Package	Inspection^{Plus} Package	Performance Package
Reduction of planned shutdown days	20,000	80,000	160,000
Reduction of unplanned shutdown days	25,000	50,000	50,000
Reduction of maintenance material	8,000	16,000	16,000
Efficiency improvements	-	-	57,600
Purchase success for maintenance material due to timely ordering	8,000	16,000	16,000
Reduction of working hours by maintenance personnel	9,500	40,000	84,000
Customer benefit per year [€/y]	70,500	202,000	383,600
Budget price of service package [€/y]	30,000	60,000	90,000
Value for the customer [€/y]	**40,500**	**142,000**	**293,600**

Table 19: Customer benefits and sacrifices expressed in monetary units added to the 'value for the customer'

To calculate the values related to the size of the boiler considered a final table was created in which the parameters according to the thermal performance of the boiler were entered. The data in Table 20 are average values for the size span of boilers under consideration. The values were determined by experience with the help of Dr. Ulrich Hohenwarter and other co-workers specialised in fluidised bed boilers.

Plant size [MW_{th}]	**50-100**	**100-200**	**200-300**
Costs of a planned shutdown day	40,000	50,000	80,000
Costs of an unplanned shutdown day	50,000	60,000	90,000
Personnel costs for maintenance works during planned shutdown	310,000	390,000	460,000
Workforce needed for a planned shutdown	15	18	20
Estimated costs of spare and wear parts during shutdown	160,000	210,000	260,000

Table 20: Constants of boilers according to size

Understandably, a look-up function was utilized in Excel in order to use the right values from Table 20 above.

The last step of the calculations was a graphical presentation of the results. This means that the added value is accumulated over 15 years for example and drawn in a graph. In diagram 3 it can clearly be seen that the most expensive package provides the highest 'value for the customer'. The main difference to the medium 'Inspection^plus' version is an efficiency improvement, which accounts for nearly € 60,000 as well as for the reduction of planned shutdown days and the reduction of working hours by doubling maintenance personnel. The cheapest version renounces most of the parts within the 'inspection + report' service resulting in a lower reduction of all potential decreases compared to the medium version. The best sold package is the 'Inspection^plus' version because of its medium price and the large amount of services nonetheless included. Customers tend to choose the medium version for psychological reasons also. One possible explanation may be that no one wants the cheapest package because they think it will be insufficient and possibly lower in quality. Moreover, people do not want to pay too high a price, therefore the medium version provides a good service at a good price, making the customer think he has made a sound deal.

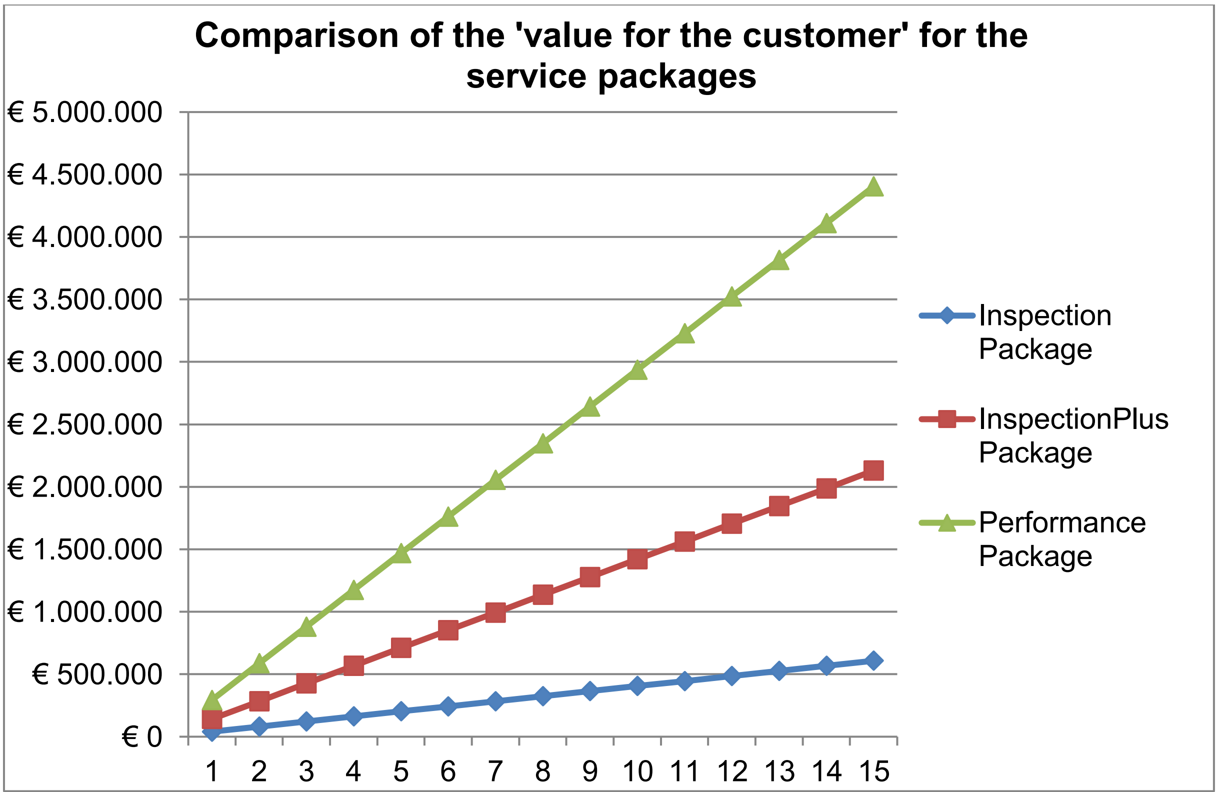

Diagram 3: Comparison of the accumulated customer value of the 'Power service' packages

This schema presented by the four tables is put into an Excel sheet and is termed the 'conclusion of customer benefits' with the actual 'value for the customer' as result. Due to the fact that ANDRITZ AG pulp and paper product group not only sells service products but also spare and ware parts as well as upgrades and modifications, this concept was conducted for all relevant 'Replacement^plus' products that are sold in addition to the packages.

The following points do not describe the products separately because the schema is the same, but the relevant calculations performed in the background are discussed to ensure completeness. To acquire a feeling of how the whole conclusion document is structured in the Appendix, the conclusion sheets are illustrated.

3.5.2 Calculation of the 'Customer Benefit' due to a reduction in sand consumption

Due to the high amount of sand needed for the operation of a fluidised bed boiler and the resultant costs, a separate calculation was defined. The calculation should later act as a sales argument for the bed material recirculation.

This equipment extracts the bed material from the boiler. In it the sand-ash mixture is separated so that the small particles can be disposed of while the rest is transported back into the boiler bed. The use of the bed material recirculation can thus save a large amount of sand since all the material removed usually has to be thrown away.

Ideally 60 kg/(h*MW) of bed material should be extracted, but in reality this rarely occurs. Therefore, the basis of the calculation is the actual amount of extraction of bed material. For this reason a table with different actual extraction volumes was created, stating the customer benefit gained by comparing the investment per year for sand with and without a bed material recirculation as well as with the ideal operation of the boiler. To simplify the calculation, a loss of bed material in the recirculating equipment equal to the amount of bed ash is assumed. Hence, the amount of bed ash from the extracted bed material must be thrown away. It can easily be seen that the amount equals the fresh sand needed for combustion if the equipment is installed. Otherwise the fresh sand fed equals the degree of extraction. This concept was then used to determine the costs for sand of a year and consequently the customer benefit.

Actual amount of bed sand extraction [kg/(h*MW)]	Sand disposal w recirculation [kg/(h*MW)]	Amount of sand recirculated [kg/(h*MW)]	Fresh sand needed [kg/(h*MW)]	Fresh sand needed in a year [kg/(h*MW)]	Costs of fresh sand for a year per MW [€/(a*MW)]	Costs of fresh sand calculated for the plant size [€/a]
10	1.7	8.3	1.7	13563.6	€ 208	€ 19,888
20	1.7	18.30	1.7	13563.6	€ 208	€ 19,888
30	1.7	28.30	1.7	13563.6	€ 208	€ 19,888
40	1.7	38.30	1.7	13563.6	€ 208	€ 19,888
50	1.7	48.30	1.7	13563.6	€ 208	€ 19,888
55	1.7	53.30	1.7	13563.6	€ 208	€ 19,888
60	1.7	58.30	1.7	13563.6	€ 208	€ 19,888

Table 21: Sand consumption with recirculation

The basis of the calculation is the actual amount of extraction of bed material. Applying this information, the costs for fresh sand with and without recirculation are calculated. As shown in the table below, first the amount of sand needed for a year is machined for both cases and later subtracted to establish the savings. To derive the costs for a year an operating time per year of 8,000 hours was assumed. The costs for fresh sand were assumed at € 15.3/ton. By plant size, a combustion plant with a thermal performance of 96 MW_{th} is implied. In Table 21 the calculation with recirculation equipment is illustrated. As can be seen the amount of bed ash remains the same due to the fact that is was calculated using the calorific value, so the value is constant when it is measured in kg/(h*MW). Table 21 likewise shows the costs calculated for the plant size in the far-right column. This value is then compared to the case without recirculation, resulting in the actual savings or the ‘customer benefit’. Table 22 below depicts the values for sand consumption without recirculation, which are then aligned with the values in Table 21. The results can be seen in Table 23.

Sand disposal without recirculation [kg/(h*MW)]	Costs of fresh sand without recirculation per MW [€/(a*MW)]	Costs of fresh sand without recirculation for the plant size [€/a]
10	€ 1,224	€ 117,300
20	€ 2,448	€ 234,600
30	€ 3,672	€ 351,900
40	€ 4,896	€ 469,200
50	€ 6,120	€ 586,500
55	€ 6,732	€ 645,150
60	€ 7,344	€ 703,800

Table 22: Sand consumption without recirculation

Savings compared with no recirculation [€/a]
€ 97, 412.40
€ 214,712.40
€ 332,012.40
€ 449,312.40
€ 566,612.40
€ 625,262.40
€ 683,912.40

Table 23: Savings in costs for sand compared to no recirculation equipment

To determine a solution quickly the values were inserted into Diagram 4 showing a comparison of savings according to the degree of extraction of bed material. Of course the benefit is greater the higher the amount of extraction. This fact is described by an increasing usage of sand when no recirculation is installed and an increasing amount of recirculation when a bed material recirculator is installed.

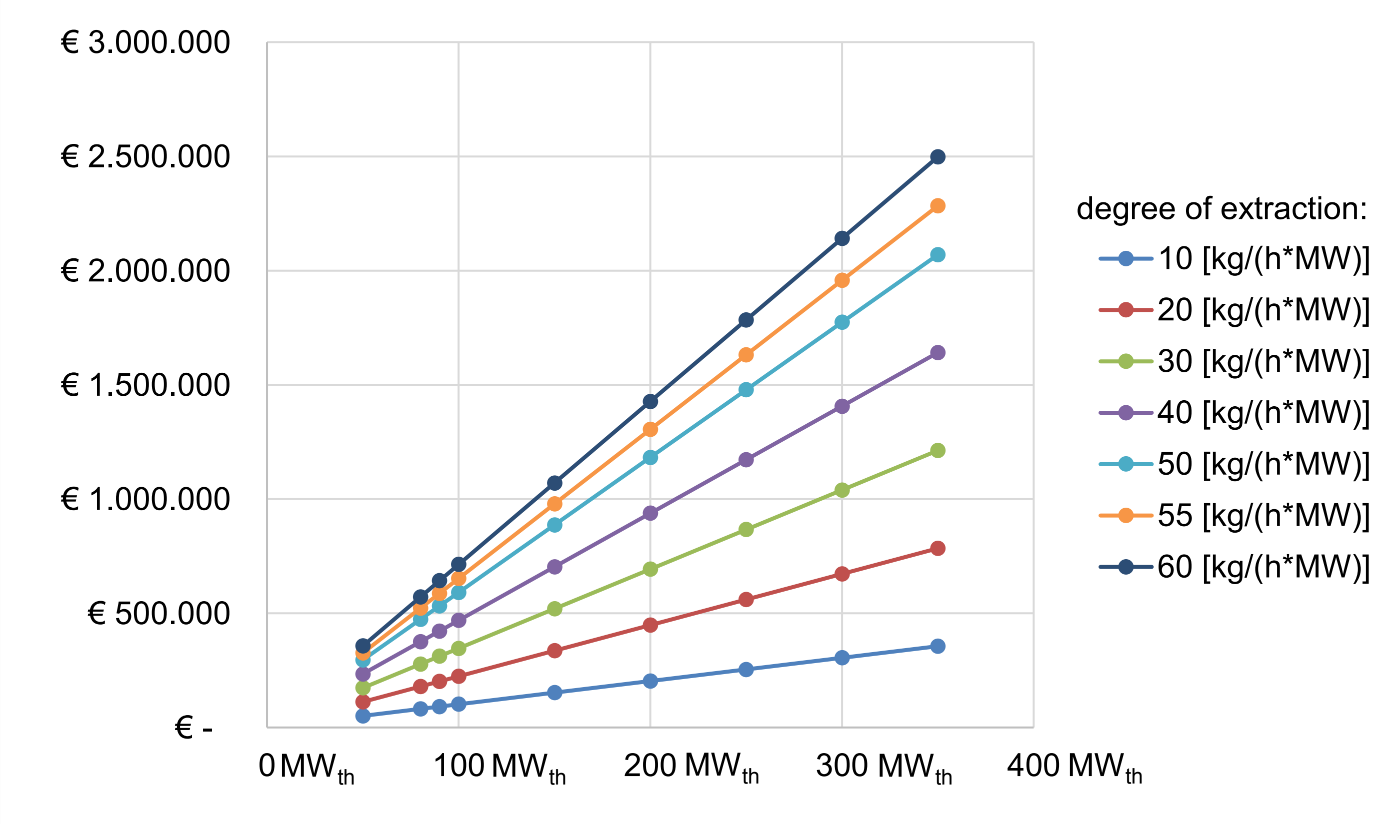

Diagram 4: Comparison of the savings according to the degree of extraction

3.5.3 Calculation of the 'Customer Benefit' due to a reduction in fuel consumption

Hundreds of tons of combustibles are burnt every year making any degree of reduction a key figure for fluidised boilers and combustion plants in total. Consequently, it was necessary to define a further calculation which is used as a basis for all equipment that reduces the amount of fuel burnt. In this particular case such systems are the pneumatic fuel feeding system, the superheater and the nozzle grids.

The pneumatic fuel feeding equipment, when installed, continuously transports the combustibles into the boiler bed having a cleaner combustion and therefore results in reduced fuel consumption. The transportation is performed by a dosing conveyor, which is directly connected to a storage silo where the combustibles are kept. On the floor of the silo there are two discharge screws transporting the fuel onto the dosing conveyor and further into the burning chamber or the boiler bed. The transportation system depends on the combustibles burnt. When burning sludge, the dosing conveyor needs to be replaced by a pump for example.

The superheater for waste fuels enables the usage of a more aggressive fuel because of a high chromium content of the surfaces. In contrast to the superheater for waste fuels the superheater RC^{plus} allows the burning of cheaper fuels with a higher ash content due to its hybrid design with double pitch but at the same identical heating surface.

Nozzle grids for waste fuels, irrespective of whether CFB or BFB, also enable the usage of a cheaper fuel. The special geometry of the grids from Andritz AG prevent plugging. This phenomenon occurs when large pieces of waste that cannot be burnt in the boiler remain in the bed and then become stuck in the nozzle grid. The result is an unplanned shutdown, which is another advantage of the nozzle grids and is described in Appendix 1. Usually the corporation operating the boiler has to buy its fuel, but in the case of waste the company disposing of the waste has to pay the combustion plant for burning their waste. Thus, being able to burn waste with larger impurities generates income because disposal is more expensive.

To determine the value for the customer the consumption of fuel was calculated using the calorific value of the fuel burnt. The fuel usage was broken down to a fuel usage per 1 MW so the savings can be calculated for every plant size.

The unit of the calorific value of fuel is:

$$\left[\frac{MJ}{kg}\right]$$

Dividing 1 by the calorific value gives:

$$\frac{\left[\frac{MW}{MW}\right]}{\left[\frac{MJ}{kg}\right]}$$

Reducing the fraction results in:

$$\left[\frac{MW * kg}{MJ * MW}\right]$$

Due to the fact that 1 [MW] is the same as 1 [MJ/s] the upper MW can be replaced giving the result:

$$\frac{\left[\frac{MJ * kg}{s}\right]}{MJ * MW}$$

Now reducing the fraction gives the amount of fuel used per second and megawatt:

$$[\frac{kg}{s * MW}]$$

After the transformation the fuel consumption is calculated for a year, which is defined by the operating time. Usually a plant operates 8,000 hours calculated on the basis of the hours in a year minus the duration of the yearly planned shutdown and an estimated average downtime due to unplanned shutdowns. The result is then multiplied with the thermal performance of the plant making this calculation usable for every plant size. The result is then transformed into monetary values, according to the average costs of the fuel that is burnt. In order to establish the savings, the costs of a year are multiplied by a percentage factor characterizing the amount of reduction.

To summarise, a reduction of fuel costs always evolves from the ability to use a cheaper fuel in the case of natural combustibles or the possibility to burn more fuel and therefore increase income when burning waste.

3.5.4 Calculations of the 'Customer Benefit' for the vortex finder

The vortex finder is the only product where a service life increase is calculated. The reason is that the vortex finder, only used in circulating fluidised bed boilers, has a big impact on the erosion corrosion of the flue gas. As a result, the parts of the boiler situated behind the vortex finder experience an increase of service life.

The vortex finder achieves this by better separating particles from the flue gas stream. The particles are separated into the cyclone where they are fed back into the burning chamber. The function of CFB and BFB boilers is discussed in detail in section 2.3.

The supervisor of this thesis created a calculation to estimate the reduction of erosion by using the data of a customer of Klabin as basis. The reduction is achieved by two factors:

- reduction of particle diameter, reducing erosion by 20% and
- a decrease of fly ash, reducing erosion by 15%.[76]

This adds up to a reduction of 35% resulting in an increase of service life of:

- 4 to 6 years in the case of the heat surfaces and
- 3 to 4 years for the protection shells.[77]

Based on the calculated values a difference of depreciation for the effected parts is determined. The savings are gained by using the price for certain equipment, which is divided by the old and the new service life. The difference of these two values is then the money saved per year. To recapitulate, for every effected part the total customer benefit is determined. Table 24 illustrates the calculations performed. The values derived are then entered in a table consisting of the entire benefits of a certain product.

[76] Cf. ANDRITZ AG internal data
[77] Cf. ANDRITZ AG internal data

	Service life			Actual costs/year [k€/a]		
	before [a]	after [a]	**Actual costs [k€]**	old lifespan	new lifespan	**Savings [k€/a]**
Heat surfaces	4	6				
Superheater for standard/waste fuels			600	150.00	100.00	50.00
Superheater RC plus			550	137.50	91.67	45.83
Superheater for bed material cooler			400	100.00	66.67	33.33
Wing walls			1500	375.00	250.00	125.00
Economiser			550	137.50	91.67	45.83
Protection shells	3	4	50.5	12.63	8.42	4.21
					∑	**304.21**

Table 24: ‘Customer benefits’ due to an increase of service life

3.5.5 Calculations of the ‘Customer Benefit’ due to changes in emissions regulations

In the case of the second topic discussed, namely the emissions regulations that will be changed in 2020, an attempt was also made to calculate a value for the customer. The first attempt at determining a benefit was to roughly calculate the costs for a plant and subtract the CAPEX for a certain reduction measure. The thinking behind the first approach was whether to buy a new plant or modify the existing one. The savings would then be the difference between the investment for a plant and the expenses for certain modifications. However, the concept was insufficiently precise and was replaced by the following model:

The concept was to compare the expenses of two cases. In the first case the customer buys a modification that reduces emissions to the prescribed level. This enables the customer to operate the existing boiler until the end of its service life. In the second the boiler operating company does not modify the boiler according to the new emissions regulations. In this case the operating company has to purchase a new boiler which will be commissioned in 2021, and shut the old boiler down at the same time. The savings resulting from this way of thinking are the difference between the expenses for both cases. How the expenses are defined can be seen in the diagram below. CAPEX1 shown is the sum of the expenses for the old boiler, the new boiler and the modification, divided by the service life of both boilers. CAPEX2 is calculated in the same way as CAPEX1 but without the expense of the modification and a shorter total service life.

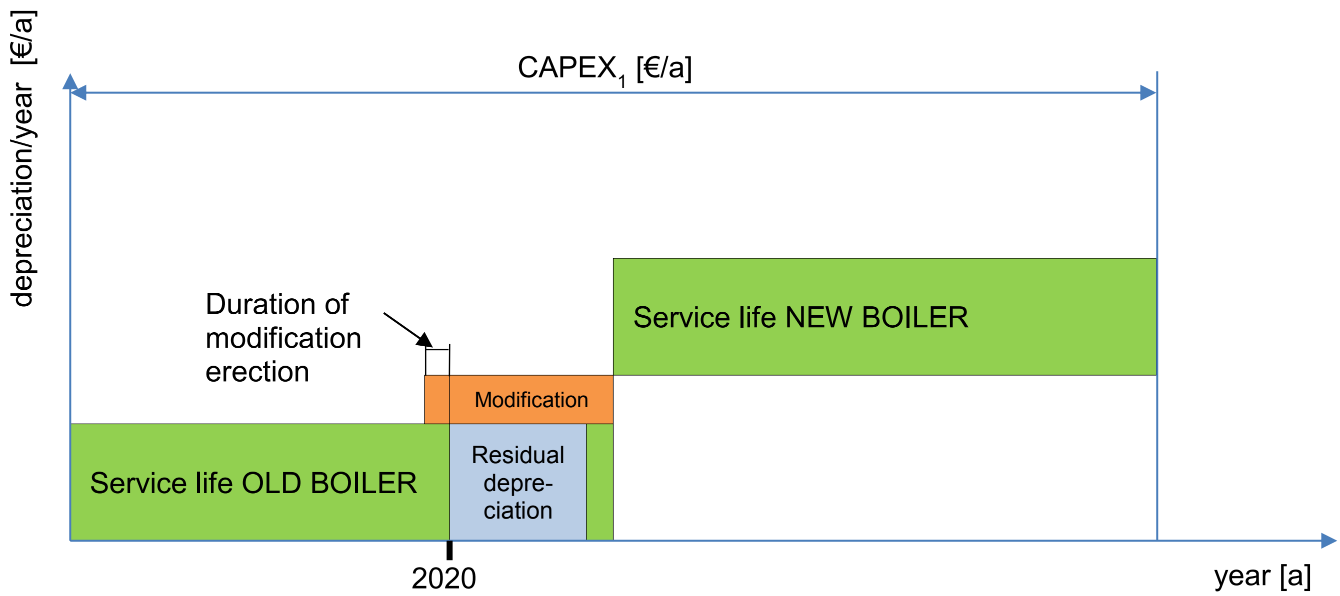

Figure 12: Replacement investment with modification

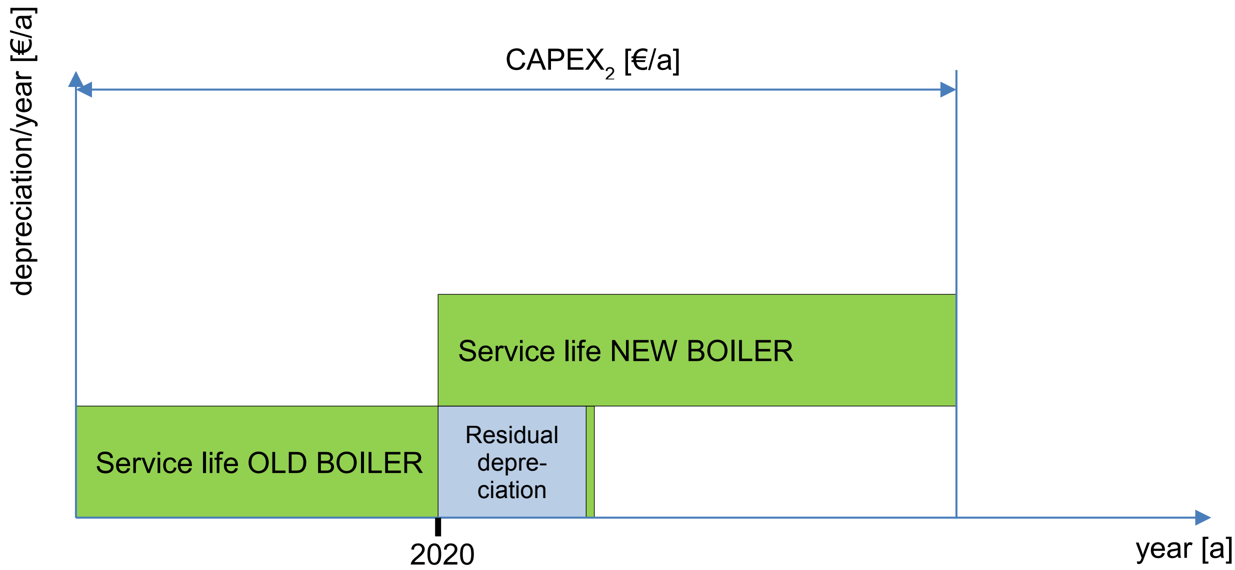

Figure 13: Replacement investment without modification

Unfortunately, the concept was rejected with the conclusion that a handling tool is sufficient because only the sales division will make use of the emissions sheet discussed in point 3.6.1. For companies operating a fluidised bed boiler it is mandatory to meet the new standards for emissions, therefore arguing with the replacement investment was not feasible.

3.6 The Emission regulations

Emissions nowadays are a trending topic in that virtually every country is now reducing their emissions to a level prescribed in the Paris climate protection treaty. Furthermore, new regulations for combustion plants emerged as a result of the Paris treaty. Consequently, this section will focus on the emission regulations that were determined on 31st of July 2017 and will come into effect in 2020.

Obviously, this creates a simple way to establish a relationship to a customer because a corporation needs to make changes to satisfy the new regulations. Therefore, the ideal moment has come to step in and offer modification services in advance. Moreover, it is an excellent way to sell service products also.

3.6.1 The emissions Excel sheet

A table summarising the limits of the relevant pollutants was compiled with the help of the new version of the Best Available Techniques Reference Document (BREF) for emissions regulations developed under the Integrated Pollution Prevention and Control (IPPC) Directive and the Commission Implementing Decision (EU) 2017/1442 of 31st of July 2017 establishing Best Available Techniques (BAT) conclusions, under Industrial Emission Directive 2010/75/EU of the European Parliament and of the Council for large combustion plants of 24 November 2010 on industrial emissions. The aim is to familiarise potential customers with the previous regulations and to indicate the value to which the emissions must be reduced. Using the data of the European Parliament percentage values were derived indicating by how much the emissions need to be reduced to meet the new standards which will be mandatory in 2020.

The next consideration was a differentiation according to the limits. Due to the fact that the old emission regulations are fixed values (no ranges) and that every molecule in the new emission regulation has different value ranges, it was apparent that three cases could be distinguished. A restriction can be met at different limits, the emissions can be reduced to the upper or lower limit of the range but also to the median of the range. Consequently, the cases were named maximum, minimum and average reduction. However, further differentiations had to be made because with miscellaneous fuels and plant sizes different restriction boundaries need to be fulfilled. Therefore, it was necessary to distinguish between plants with a thermal performance of <100 MW_{th}, 101 MW_{th} – 300 MW_{th}, >300 MW_{th} . Needless to say, every relevant combustible is divided into the afore-mentioned classifications. After establishing these distinctions, measures were entered needed to meet the amount of reduction and with that the Capital Expenditure (CAPEX) a company will approximately have to invest. The Excel sheet includes the most important emissions, which are NOX, SO2 and dust polluted by the most widespread fuels used in fluidised bed boilers ranging from biomass and peat to coal, gas and waste.

The challenge was to identify the right measures for the actual amount of reduction required because no two plants are equal. Every plant has different built-in modules which change the measures that need to be implemented. For example, a plant can have a wet scrubber or a dry scrubber installed, which changes the measures necessary to reduce the amount of SO_2 when burning coal. Hence, the correct modifications may only be determined by gained experience. The supervisor at ANDRITZ AG of this master thesis, Dr. Ulrich Hohenwarter, succeeded in determining the right measures needed. The fact that Andritz AG possesses little information about plants that are currently in use, irrespective of whether the product has been built by a competitor or not, increases the difficulty of defining the appropriate measures.

A small part of the Excel sheet is described below in order to show the cases discussed within this subsection

COAL Coal, lignite and other solid fuels (no biomass and no peat)	IED 2010/75/EU Appendix V Part 2 (existing plants appr. bef. 2013) valid after 1.1.2016			BAT-AELs binding from 2021 yearly average(1) (daily average)			COAL Coal, lignite and other solid fuels	Efficiency needed Maximum case Existing Plant put into operation **after** 7.1.2014			Efficiency needed Average case Existing Plant put into operation **after** 7.1.2014			Efficiency needed Minimum case Existing Plant put into operation **after** 7.1.2014		
				Existing plant												
	50-100 MW_{th}	**100-300 MW_{th}**	**>300 MW_{th}**	**50-100 MW_{th}**	**>100 MW_{th}**	**>300 MW_{th}**		**50-100 MW_{th}**	**>100 MW_{th}**	**>300 MW_{th}**	**50-100 MW_{th}**	**>100 MW_{th}**	**>300 MW_{th}**	**50-100 MW_{th}**	**>100 MW_{th}**	**>300 MW_{th}**
SO_2 (mg/Nm³) [6%O2]	400	250	200	150 - 360 (170 - 400)	95 - 200 (135 - 220(12))	FB20 - 180 PC10 - 130 (FB25 - 165(13) PC50 - 220)	**SO_2 removal**	62.5%	62%	FB 90% PC 95%	36.25%	41%	FB 50% PC 65%	10%	20%	FB 10% PC 35%
							to reach [mg/Nm³]	150	95	FB 20/ PC 10	255	147,5	FB 100/ PC 70	360	200	FB 180/ PC 130
WET scrubber installed							Measure:	**REA plus module (KRP)**	**REA plus module (KRP)**	**REA plus module (KRP)**	**REA plus module (KRP)**	**REA plus module (KRP)**	**REA plus module (KRP)**	**Absorber tuning (new spraying layer)**	**Absorber tuning (new spraying layer)**	**Absorber tuning (new spraying layer)**
							CAPEX Estimate: [k€]	**1000 - 2000**	**2000 - 3000**	**3000 - 4000**	**1000 - 2000**	**2000 - 3000**	**3000 - 4000**	**300 - 400**	**400 - 800**	**800 - 2000**
DRY scrubber installed							Measure:	**add. reactor + add. hydrator**	**add. reactor + add. hydrator**	**new FGD plant**	**add. reactor + add. hydrator**	**add. reactor + add. hydrator**	**new FGD plant**	**Reactor tuning + hydrator tuning**	**Reactor tuning + hydrator tuning**	**Reactor tuning + hydrator tuning**
							CAPEX Estimate: [k€]	**3000 - 4000**	**4000 - 6000**	**10000 - 30000**	**3000 - 4000**	**4000 - 6000**	**10000 - 30000**	**50 - 100**	**100 - 300**	**300 - 600**

Table 25: Emission levels for coal and their reduction measures

To increase the usability of this sheet a handling tool was created that helps to determine to what extent a company has to reduce its emissions, and the approximate cost of such a measure. By entering the number of tons of steam produced, the current emission value, the pollutant and the fuel that is fired in the boiler, the tool shows exactly what should be reduced, thereby doing away with the need to search for the appropriate values in tables. All data is provided by the supervisor of this master thesis and is derived from experience.

3.6.2 Measures to reduce the emission

- **Wet limestone flue gas desulphurisation (WFGD):** The system consists of an open spray tower through which the flue gas flows. In FGD limestone slurry absorbs more than 99% of the SO2 contained in the flue gas but HCL and HF are also removed. The limestone reacts with the SO2 and creates gypsum as a by-product. Moreover, other absorbents can be used. For example, fibre-reinforced plastic absorbers, reinforced concrete absorbers with polypropylene linings are used in addition to stainless steel and alloy absorbers, and carbon steel absorbers with different linings. The system can be used for nearly every combustible (lignite, hard coal, oil, biomass and waste). The illustration below shows a WFDG module with the raw gas entering on the left side and leaving the equipment on the right. The middle section where the gas is cleaned shows the injection of the absorbing material with its connection to the tank as well as a solid absorber above the injection.[78]

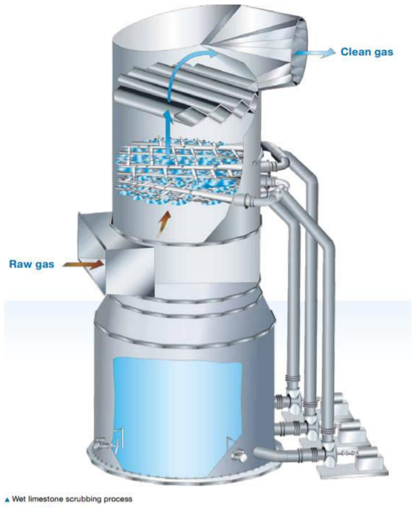

Figure 14: Concept of a WFGD[79]

- **Dry flue gas cleaning systems:** Dry cleaning systems are based on circulating fluidised bed technology. The flue gas flows through a cylinder or scrubber behind which a filter is installed. The bed material in the scrubber, consisting of limestone, by-products and fly ash, is recirculated through the scrubber and the filter until clean gas exits the system. In addition, water is injected into the CFB apparatus to increase SOx absorption and thus minimize the amount of absorbents needed to meet the required emission level. This process is termed dry flue gas cleaning because the by-product created in the equipment is a dry powder that can be landfilled or used as filler for road construction for example.[80]

  - **Dry sorbent injection:** Is equipment employed to remove SOx and/or HCL if the space available is small. Hydrated lime is used in the system to neutralize the pollutants, whereas carbon injection can be used to reduce the proportion of heavy metals and dioxin/furan. In addition, a bag filter for particulate matter is utilised because dust and by-products need to be filtered afterwards.[81]

  - **Sodium bicarbonate:** Sodium bicarbonate is a highly reactive absorbent and is therefore employed if minimum waste production is required.[82]

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78 Cf. https://www.andritz.com (10.01.2018)
79 https://www.andritz.com (10.01.2018)
80 Cf. https://www.andritz.com (10.01.2018)
81 Cf. https://www.andritz.com (10.01.2018)
82 Cf. https://www.andritz.com (10.01.2018)

- **TurboSorp:** The TurboSorp is constructed using a CFB unit with a baghouse filter after the cylindrical section. The sorbent particles are recirculated multiple times through these two parts until the gas is clean. [83]

SNCR (Selective Non-Catalytic Reduction):
The SNCR is a reduction system for filtering NOx from flue gas. The difference to the SCR is that no catalysts are needed to ensure that ammonia or urea is directly sprayed into the flue gas after the vortex finder, as shown in Figure 15.

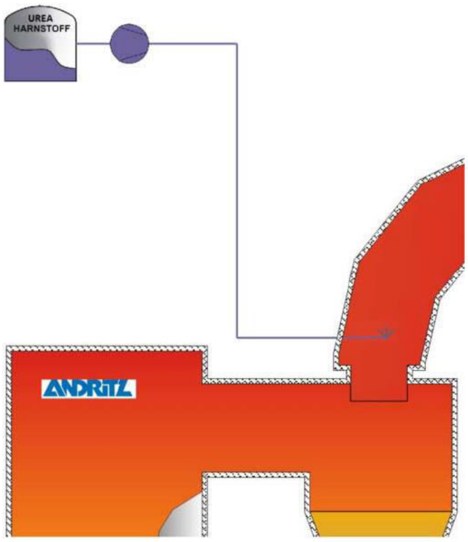

Figure 15: SNCR location in the combustion plant[84]

Depending on the additive the chemical formula is:
“Urea: $NH_2CONH_2 + 2\ NO + \frac{1}{2}\ O_2 \rightarrow 2N_2 + CO_2 + 2H_2O$
Ammonia: $4NH_3 + 4NO + O_2 \rightarrow 4N_2 + 6H_2O$”[85]

SCR (Selective Catalytic Reduction):
This system is used to reduce the amount of NOx in the flue gas created by high-temperature combustion. The function of the SCR is to reduce NOx by transforming it into nitrogen and water vapour. The gas flows through catalysts in which an aqueous urea solution is injected to fulfil the chemical reduction. The catalysts are utilised to accelerate the conversion to the end products.[86]
“$4NH_3 + 4\ NO + O_2 \rightarrow 4\ N_2 + 6\ H_2O$
$8\ NH_3 + 6\ NO_2 \rightarrow 7\ N_2 + 12\ H_2O$”[87]

[83] Cf. https://www.andritz.com (10.01.2018)
[84] ANDRITZ AG internal data
[85] http://www.ms-umwelt.de (07.01.2018)
[86] Cf. http://www.energiewelten.de (07.01.2018)
[87] http://www.vivis.de (07.01.2018)

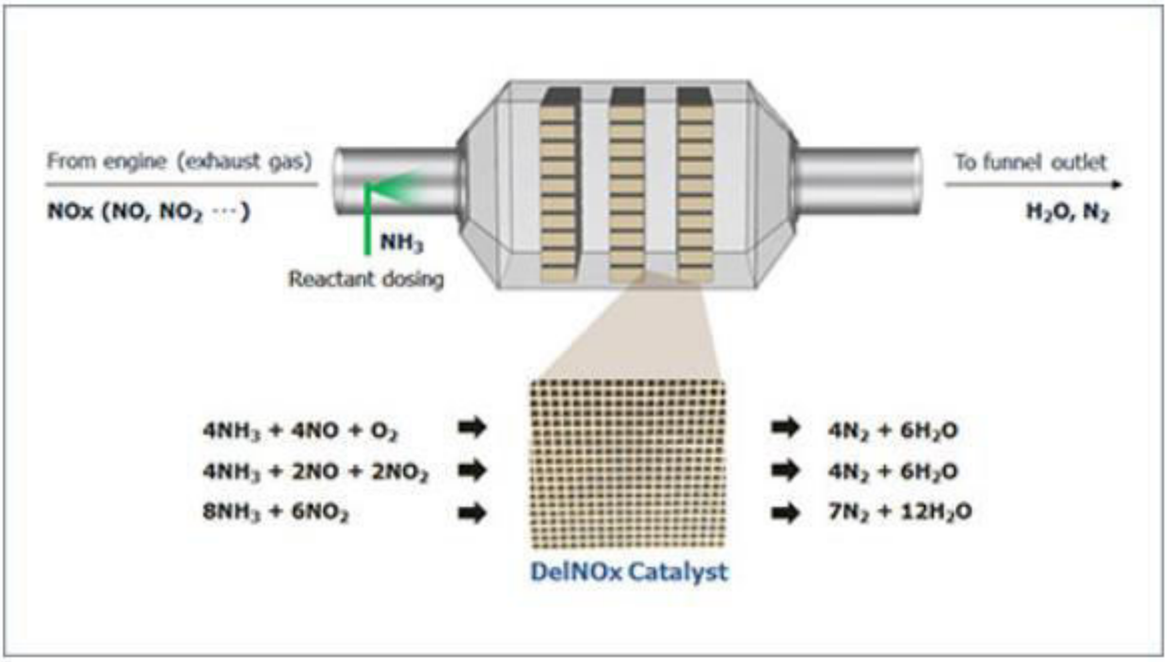

Figure 16: SCR working principle[88]

- **Hybrid solutions (SNCR + SCR)**

- **Bag house filter:** As shown in Figure 17 below, the bag house filter is a chamber in which many bags are installed. Through these bags the flue gas flows bottom up, whereas the filter surface contains absorbents such as Ca(OH)2 or sodium carbonate and activated carbon. The gaseous or dissolved substances precipitate on the surface of the bag thereby blocking the filter. In order to clean the system, the gas stream is simply reversed. By doing so, the substances drop from the filter surface and are collected for disposal. The photo on the left shows a bag house with many small bags. On the right, the cleaning procedure is described.[89]

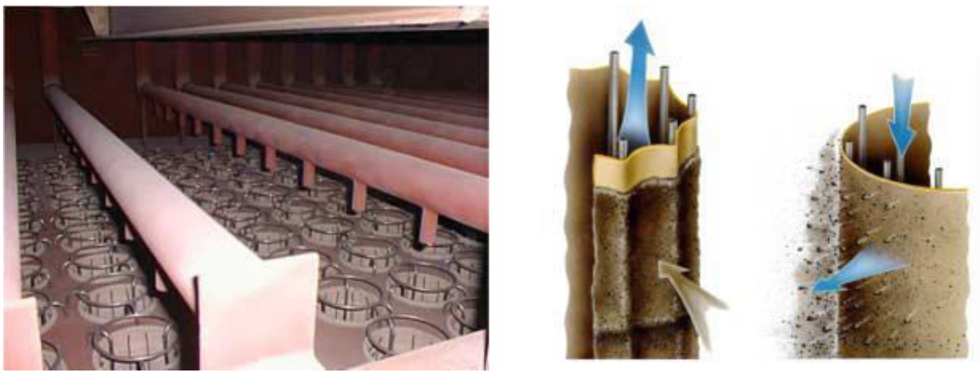

Figure 17: Installed bag house filter (left) and working principle (right)[52]

[88] http://www.doosanengine.com (08.01.2018)
[89] ANDRITZ AG internal data

- **ESP (Electrostatic Precipitator):** This is used to remove particulate matter from the gas stream. The system is electrostatically charged and thus attracts the PM or dust from the gas.[90]

  - **WESP (Wet Electrostatic Precipitator)**
    The WESP is utilized in order to filter sub-micron particulate and aerosols. The system is able to collect matter from dust down to PM 2.5 [91]

  - **Dry ESP:** Is usually part of a CFB scrubber system.[92]

[90] Cf. https://www.andritz.com (10.01.2018)
[91] Cf. https://www.andritz.com (10.01.2018)
[92] Cf. https://www.andritz.com (10.01.2018)

4 Conclusion and Outlook

Being able to translate benefits into monetary units is crucial for every business. Today customer research is being conducted on a huge scale to define customer needs and to be able to design the product according to the data collected. Determining the value for the customer in the B2B area can be explicitly expressed for the most part by changes in income or quality. The B2C area on the other hand is more complex because customers generally decide what product to purchase on an emotional basis.

Defining the data posed a significant problem. ANDRITZ AG possesses little information about competitors. Therefore, a comparison with own products or with not having regarded product built in was the only possibility to derive a 'value for the customer'. A further problem was that the data needed for the calculation, that is to say the variables and constants, could for the most part only be determined by experience. There were only a few employees at ANDRITZ AG able to define the data to render the calculations correct. The solution was to use safe data, whereby numbers were defined such that the calculations show results that are a little lower than they would be in reality. Nonetheless, the results are impressive.

The calculations show an amazingly high saving potential for sand consumption and fuel reduction. The savings for sand are evaluated at about 1,000 – 7,000 €/(a*MW), creating savings for a plant with a steam production of 115 t/h amounting to 100,000-700,000 [€/a]. With regard to fuel usage, a saving of about 2,640 €/(a*MW) was derived. The result was calculated for biomass (12 €/t) with an average calorific value of 6.37 MJ/kg and a reduction of fuel usage of just 5%. Another fascinating result was the value of the service packages with an incredible saving of 70,000 – 380,000 €/a depending on the service package itself. The value does not include the price of the package.

Consequently, ANDRITZ AG should focus on this topic to improve customer relations and its understanding of the customer's wishes and needs. It is this understanding which drives the market position and generates a competitive advantage. In the B2B area the companies should focus more on the emotional and qualitative benefits. These hardly translatable benefits usually constitute the biggest difference between an enterprise and the competition.

The startlingly huge amount of sand used and fuel burnt every year is perturbing. Considerable financial resources can be saved here. Thus, improving particular equipment further is crucial for reducing the consumption of natural resources and, therefore, making combustion plants more economically friendly.

In conclusion, the future strategy of Andritz AG should focus on implementing more sophisticated forecasting and CRM tools to be able to determine competitors' data and thus enable better price planning and a more widespread range of benefits. Currently, their usage is more or less voluntary and consequently poorly maintained. Enhancing both would definitely improve customer relations and the volume of orders by reacting early, maybe even before the potential customer knows. In addition, the number of employees in the sales force should be increased to provide key account management for the largest customers. As a consequence of these facts, the issue of value of the customer will gain importance and should be focused on. Customer lifetime values must be calculated. Customer differentiation needs a new concept, and key account management should be boosted during the next few years.

The completion of the scientific paper has shown that a correct and accurate translation of benefits in monetary units is a great challenge. The generalization of the calculations is very difficult. The reason is the large number of factors one advantage influences and above all the strongly situation-dependent conditions. Another hurdle in the calculation of "value for the customer" is the complexity of the benefits that had to be reduced in order to ensure the comprehensibility of the arguments. At the same time, as many influencing factors as possible should be taken into account in order to create a realistic picture of the benefits.

In the case of emissions, a continuous improvement process is necessary in order to one day stop global warming. Measures to reduce pollutants need to be continuously improved. On the basis of the theoretical section, it is clearly apparent that combustion plants are one of the biggest contributors to global warming. One reason to push a reduction is that the burning of combustibles will be necessary for many more years but minimum until nuclear fusion is commercially useable. I personally believe the emission limits stated in the BREF should not be defined by ranges. There should be fixed values for reduction without any leeway.

The problem arising from the issue of emissions was that no real customer benefit could be calculated, this being an insufficient sales argument due to the fact that the customer needs to meet the regulations anyway, and therefore does not decide according to monetary savings. Moreover, defining the right measures for the right pollutants and for the prescribed amount of reduction was only possible with the vast experience of Dr. Ulrich Hohenwarter. The reason is that the effectiveness of reduction measures greatly depends on the operation parameters as well as the surroundings and the law in the country concerned.

Perhaps in the future European combustion plant operators will collaborate on improving measures to reduce greenhouse gases. The approach of selling modifications to operate the plant beyond 2020 is an attractive way of making money but is not really future orientated. Every plant should incorporate all reduction measures without exception.

For Andritz AG this topic will not be relevant much beyond 2020 because all European plants will adopt the new emissions regulations. The work is done, and the tool created will be forgotten. But maybe this is a reason to continue to push emission reduction measures for the next emissions regulation reform.

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Abbreviations

AG	Aktiengesellschaft
IPPC	Integrated Pollution Prevention and Control
IED	Industrial Emissions Directive
BAT	Best Available Technique
BREF	Best Available Technique Reference Document
LCP	Large Combustion Plants
BFB	Bubbling Fluidised Bed Boiler
CFB	Circulating Fluidised Bed Boiler
B2B	Business to Business
FGD	Flue Gas Desulphurisation
WFGD	Wet Flue Gas Desulphurisation
RDF	Residue Derived Fuel
FGC	Flue Gas Conditioning
USP	Unique Selling Proposition
CLV	Customer Lifetime Value
CE	Customer Equity
M	Measurable
C	Calculable
D	Decidable
H	High
M	Medium
L	Low
ROI	Return on Investment

Appendix

Appendix 1: Nozzle grid calculation

Added Value due to the usage of *nozzle grids* from Andritz AG

ANDRITZ Pulp & Paper

Boiler [MW_{th}]	90 MWth
Steam production [t/h]	108 t/h
calorific value of the fuel (biomass)	6,37 MJ/kg
Average Lifecycle [y]	10 y

Average costs per ton steam	30	€/t
Operation time per year	8000	h
Average boiler efficiency	90%	
Estimated costs of a planned shutdown day of the boiler	40000	€/d
Estimated costs of an unplanned shutdown day of the boiler	50000	€/d
Estimated personnel costs of maintenance works during planned shut down	172000	€
Workforce needed for planned shutdown	15	pers
Workforce needed for unplanned shutdown	4	pers
Duration of planned shutdown	10	d
Working hours per shutdown day	20	h
Hourly rate (welder, fitter)	50	€/h
costs for waste	50 €/t - 60 €/t	
costs for biomass	12 €/t - 23 €/t	

	Nozzle grid for BFB with		Nozzle grid for CFB with	
Expected potential of improvements due to service packages	**standard fuel**	**waste fuel**	**standard fuel**	**waste fuel**
Reduction of unplanned shutdown days [d]	0,5	1	1	1
Reduction of fuel costs [%]	0	0,05	0	0,05

	Nozzle grid for BFB with		Nozzle grid for CFB with	
Expected potential of improvements due to service packages for selected	**standard fuel**	**waste fuel**	**standard fuel**	**waste fuel**
Reduction of unplanned shutdown days	€ 20.000,00	€ 40.000,00	€ 40.000,00	€ 40.000,00
Reduction of fuel costs	€ -	€ 1.017.268,45	€ -	€ 1.017.268,45
Customer benefit per year [€/a]	€ 20.000,00	€ 1.057.268,45	€ 40.000,00	€ 1.057.268,45
Budget price of service package [€]	€ 200.000,00	€ 200.000,00	€ 200.000,00	€ 200.000,00
Value for the customer for the product lifetime [€]	**€ -**	**€ 10.372.684,46**	**€ 200.000,00**	**€ 10.372.684,46**

Appendix 2: Bed material recirculation calculation

Added Value due to the usage of a *bed material recirculation* from Andritz AG

Boiler [MW_{th}]	90	MWth
Steam production [t/h]	108	t/h
Actual amount of extraction	50	
Average Lifecycle [y]	10	y

Average costs per ton steam	30	€/t
Operation time per year	8000	h
Average boiler efficiency	90%	
Estimated costs of a planned shutdown day of the boiler	40000	€/d
Estimated costs of an unplanned shutdown day of the boiler	50000	€/d
Estimated personnel costs of maintenance works during planned shut down	310000	€
Estimated costs of spare and wear parts during shutdown	160000	€
Workforce needed for planned shutdown	15	pers
Workforce needed for unplanned shutdown	4	pers
Duration of planned shutdown	10	d
Working hours per shutdown day	20	h
Hourly rate (welder, fitter)	50	€/h

Expected potential of improvements due to service packages	**Bed material recirculation**
Reduction of Sand amount used per day	according to the amount of bed ash

Expected potential of improvements due to service packages for selected boiler [€]		**Bed material recirculation**
Reduction of costs for fresh Sand	€	532.122,95
Customer benefit per year [€/a]	€	532.122,95
Budget price of service package [€]	€	100.000,00
Value for the customer for the product lifetime [€]	€	5.221.229,51

Appendix 3: Pneumatic fuel feeding system calculation

Added Value due to the usage of *pneumatic fuel feeding* system from Andritz AG

Boiler [MW_{th}]	90 MWth	
Steam production [t/h]	108 t/h	
calorific value of the fuel (biomass)	6,37 MJ/kg	
Average Lifecycle [y]	10 y	
Average costs per ton steam	30	€/t
Operation time per year	8000	h
Average boiler efficiency	90%	
Estimated costs of a planned shutdown day of the boiler	40000	€/d
Estimated costs of an unplanned shutdown day of the boiler	50000	€/d
Estimated personnel costs of maintenance works during planned shut down	310000	€
Estimated costs of spare and wear parts during shutdown	160000	€
Workforce needed for planned shutdown	15	pers
Workforce needed for unplanned shutdown	4	pers
Duration of planned shutdown	10	d
Working hours per shutdown day	20	h
Hourly rate (welder, fitter)	50	€/h
costs for waste	50 €/t - 60 €/t	
costs for biomass	12 €/t - 23 €/t	

Expected potential of improvements due to pneumatic fuel feeding systems	standard fuel	waste
Reduction due to cheaper fuel or increase in revenue	2%	5%
	5%	
	7%	
	10%	

Expected potential of improvements due to pneumatic fuel feeding systems		standard fuel min case (12 €/t))	standard fuel max case (23 €/t))	waste min case (50 €/t))	waste max case (60 €/t))
Customer benefit per year [€/a]	**2%**	**€ 97.658**	**€ 187.177**		
	5%	**€ 244.144**	**€ 467.943**	**€ 1.017.268**	**€ 1.220.722**
	7%	**€ 341.802**	**€ 655.121**		
	10%	**€ 488.289**	**€ 935.887**		
Budget price of service package [€]	**300000**				
Value for the customer for the product lifetime [€]	2%	€ 676.577,71	€ 1.571.773,94		
	5%	€ 2.141.444,27	€ 4.379.434,85	€ 9.872.684,46	€ 11.907.221,35
	7%	€ 3.118.021,98	€ 6.251.208,79		
	10%	€ 4.582.888,54	€ 9.058.869,70		

Appendix 4: Superheater calculation

Added Value due to the usage of *superheater* systems from Andritz AG

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Boiler [MW_{th}]	90 MWth
Steam production [t/h]	108 t/h
Calorific value of the fuel (Biomass) [MJ/kg]	6,37 MJ/kg
Average Lifecycle [y]	5 y

Average costs per ton steam	30	€/t
Operation time per year	8000	h
Average boiler efficiency	90%	
Estimated costs of a planned shutdown day of the boiler	40000	€/d
Estimated costs of an unplanned shutdown day of the boiler	50000	€/d
Estimated personnel costs of maintenance works during planned shut down	310000	€
Estimated costs of spare and wear parts during shutdown	160000	€
Workforce needed for planned shutdown	15	pers
Workforce needed for unplanned shutdown	4	pers
Duration of planned shutdown	10	d
Working hours per shutdown day	20	h
Hourly rate (welder, fitter)	50	€/h
costs for waste	50	€/t
	-	
	60	€/t
costs for biomass	12	€/t
	-	
	23	€/t

Expected potential of improvements due to superheater usage	**SH standard fuels**	**SH waste fuels**	**SH bed material cooler**	**SH RC plus**
Reduction of unplanned shutdown days [d]	0,5	0,5	0,5	0,5
Reduction of fuel costs [%]	0,0%	10,0%	0,0%	5,0%

Expected potential of improvements due to superheater usage in selected	**SH standard fuels**	**SH waste fuels**	**SH bed material cooler**	**SH RC plus**
Reduction of unplanned shutdown days	€ 25.000,00	€ 25.000,00	€ 25.000,00	€ 25.000,00
Reduction of fuel costs	€ -	€ 488.288,85	€ -	€ 244.144,43
Customer benefit per year [€/a]	€ 25.000,00	€ 513.288,85	€ 25.000,00	€ 269.144,43
Budget price of the product [€]	€ 200.000,00	€ 200.000,00	€ 300.000,00	€ 200.000,00
Value for the customer for the product lifetime [€]	**-€ 75.000,00**	**€ 2.366.444,27**	**-€ 175.000,00**	**€ 1.145.722,14**

Appendix 5: Vortex finder calculation

ANDRITZ Pulp & Paper

Added Value due to the usage of a *Vortex finder* from Andritz AG

Boiler [MW_{th}]	90 MWth
Steam production [t/h]	108 t/h
Service life [a]	4 a

	Service life						**actual costs/year [k€/a]**		
	before [a]	after [a]	**cost range [k€]**			**actual costs [k€]**	old lifespan	new lifespan	**Savings [k€/a]**
Heat surfaces	4	6							
Superheater for standard/waste fuels			200	-	1000	600	150,00	100,00	50,00
Superheater RC plus			100	-	1000	550	137,50	91,67	45,83
Superheater for Bed Material Cooler			300	-	500	400	100,00	66,67	33,33
Wing walls			1000	-	2000	1500	375,00	250,00	125,00
Economizer			100		1000	550	137,50	91,67	45,83
Protection shells	3	4	1	-	100	50,5	12,63	8,42	4,21
								∑	**304,21**

	costs [k€]	service life [a]	costs/year [k€/a]
Vortex finder old system	250	4	62,5
Vortex finder new	250	4	62,5

Expected potential of improvements due to service packages	**Vortex finder**
Service life enhancement [a]	2

Expected potential of improvements due to service packages for selected		**Vortex finder**
Reduction of costs due to service life enhancement	€	304.208,33
Customer benefit per year [€]	€	304.208,33
Budget price of the product [€]	€	100.000,00
Added Value for the whole service life [€]	**€**	**1.116.833,33**

Appendix 6: Table of values (1)

Product	Product parts	Benefit	Value	categories: quantitative	categories: qualitative	Motif	Added Value [€]
Inspection Package	Inspection + report of pressure parts Inspection + report of fluidized bed module	Actual status of mechanical equipment	less unexpected shutdowns/ better budgeting => lower maintenance and personnel costs	✓		cost saving due to reduction of unplanned SD, purchasing success due to planning reliablility	unpl. SD-day (50-100 kE); purchasing suc. -10% of order costs (20-40 kE)
		Information on existing or future weaknesses or failures	better budgeting => lower maintenance costs	✓		purchasing success due to planning reliablility	purchasing suc. -10% of order costs (20-40 kE)
		external inspections by professionals	higher quality of information about the plant		✓	proffessional support/opinion	-
	2 days Advisory service (extra days at daily rate)	doing the right things in the right way!	lower maintenance costs	✓		cost saving/ plant reliability	reduction of maintenance costs
Inspection[plus] Package	Inspection + report of Pressure parts Inspection + report of Wall thickness measurement Inspection + report of Fuel handling system Inspection + report of Ash handling system Inspection + report of Fluidized bed module Inspection + report of Air system	Actual status of mechanical equipment, including wall thickness	less unexpected shut downs; better budgeting => lower maintenance and personal costs	✓		cost saving due to reduction of unplanned SD, purchasing success due to planning reliablility	unpl. SD-day (50-100 k€); purchasing suc. -10% of order costs (20-40 k€)
		Information on existing or future weaknesses or failures + measures recommended during next shutdown	better budgeting => lower maintenance costs	✓		purchasing success due to planning reliablility	purchasing suc. -10% of order costs (20-40 k€)
		unscheduled shutdowns avoided	higher availability => lower maintenance costs	✓		plant reliability/ cost saving	unpl. SD-day (50-100 k€)
		higher availability/increased lifetime	lower maintenance costs	✓		plant reliability/ cost saving	planned and unplanned shutdown red., maintenance material red., personnel costs
	Operations review	optimal preparation for inspection; input for further operational improvements	higher quality of inspection; higher availability		✓	plant reliability	-
	4 days Advisory service (extra days at daily rate)	doing the right things in the right way!	lower maintenance costs		✓	plant reliability/ cost saving	reduction of maintenance costs
Performance Package	Inspection + report of Pressure parts Inspection + report of Wall thickness measurement Inspection + report of Fuel handling system Inspection + report of Ash handling system Inspection + report of Fluidized bed module Inspection + report of Air system	Actual status of mechanical equipment, including wall thickness	less unexpected shut downs; better budgeting => lower maintenance and personal costs	✓		cost saving due to reduction of unplanned SD, purchasing success due to planning reliablility	unpl. SD-day (50-100 k€); purchasing suc. -10% of order costs (20-40 k€)
		Information on existing or future weaknesses or failures + measures recommended during next shutdown	better budgeting => lower maintenance costs	✓		purchasing success due to planning reliablility	purchasing suc. -10% of order costs (20-40 k€)
		unscheduled shutdowns avoided	higher availability => lower maintenance costs	✓		plant reliability	unpl. SD-day (50-100 k€)
		higher availability/increased lifetime	lower maintenance costs	✓		plant reliability/ cost saving	planned and unplanned shutdown red., maintenance material red., personnel costs red.
	Operations review	optimal preparation for inspection; input for further operational improvements	higher quality of inspection; higher performance	✓		plant reliability/ higher revenue	planned and unplanned shutdown red., maintenance material red., personnel costs red., output increase
	4 days Advisory service (extra days at daily rate)	doing the right things in the right way!	lower maintenance costs		✓	cost saving/ plant reliability	reduction of maintenance costs
	General shutdown planning	identification and definition of activities during SD and required measures	lower maintenance costs/ shorter SD time	✓		plant reliability/ cost saving due to accurate planning	planned shutdown reduction, maintenance material and personnel reduction
		scheduling of activities	lower maintenance costs/ shorter SD time	✓		plant reliability/ cost saving due to accurate planning	planned shutdown reduction, maintenance material and personnel reduction
		personnel planning performed by external specialist	lower maintenance costs/ shorter SD time	✓		plant reliability/ cost saving	planned shutdown reduction, maintenance material and personnel reduction
		preparation of tender documents of the works by a specialist	lower maintenance costs/ shorter SD time	✓		plant reliability/ cost saving	planned shutdown reduction, maintenance material and personnel reduction
	Start-up support	2 day on-site engineering support by a boiler specialist - optimization of the operation with current boiler status	higher availability and higher efficiency	✓		plant reliablility/ cost saving due to a shorter start up phase	planned and unplanned shutdown red., maintenance material red., personnel costs red., output increase
		written guide for the boiler operation with the current fuel and setup	higher availability and higher efficiency	✓		plant reliablility, cost saving due to high efficient operation	planned and unplanned shutdown red., maintenance material red., personnel costs red., output increase
Service Package Options	Shutdown work, including supervision	shutdown work performed by experts	time saving => personnel costs saving	✓		cost saving	personnel cost reduction
	Supplying spare and wear parts	directly from OEM	assured mountability		✓	reliability of the service	-
	Annual safety function check (check, report, certificate)	safety functions meet the safety standards	saving penalty costs/ less accidents	✓		cost saving/ plant safety	penalty costs red.
	Online monitoring (Metris) and operational troubleshooting on demand at hourly rates	fast determination of the root of an error	higher availability and higher efficiency		✓	plant reliablility, cost saving due to high efficient operation	planned and unplanned shutdown red., maintenance material red., personnel costs red., output increase
		fast reaction to errors possible	time saving => shorter unplanned downtime => lower maintenance costs		✓	cost saving/ plant reliability	unplanned shutdown red., maintenance material red., personnel costs red., output increase
	24/7 service hotline	fast service support	time saving =>shorter unplanned downtime => lower maintenance costs		✓	cost saving/ plant reliability	unplanned shutdown red., maintenance material red.,

Appendix 7: Table of values (2)

Superheater for standard fuels	frequent quality checks in the workshops ensure excellent fabrication and welding quality	less manufacturing mistakes possible => lower probability of unplanned SD	✔		plant reliability/ cost saving	**unplanned shutdown red., maintenance material red., personnel costs red.**
	wide range of materials ensure the optimum balance between resistance to corrosion/erosion and material costs	lower investment costs		✔	cost saving	**planned shutdown red., maintenance material red., personnel costs red.**
	perfect adaption to use	higher performance => higher revenue		✔	higher revenue	**output increase**
Superheater for waste fuels	top quality and high chromium content enable the use of more agressive fuels	lower costs for fuel	✔		cost saving	**fuel costs reduction,**
	excellent resistance against corrosion and erosion	longer lifetime => lower maintenance costs	✔		plant reliability/ cost saving	**maintenance material, personnel, planned and unplanned shutdown reduction**
	cladding or spray coating for longer lifetime are possible options	longer lifetime => lower maintenance costs	✔		plant reliability/ cost saving	**maintenance material, personnel, planned and unplanned shutdown reduction**
Superheater for bed material cooler	lower investment costs	lower investment costs	✔		cost saving	**investment cost reduction**
	lower erection time	lower erection time => personnel costs saving	✔		cost saving	**personnel cost reduction**
	less plugging	higher availability => lower maintenance costs	✔		plant reliability/cost saving	**planned and unplanned shutdown red., maintenance material red., personnel costs red.**
	less pressure loss	higher efficiency => higher revenue	✔		higher revenue	**output increase**
	better heat transfere	higher performance => higher revenue	✔		higher revenue	**output increase**
Superheater RC^{plus}	perfect cooling and excellent heat surface alignment	higher perfomance => higher revenue	✔		higher revenue	**output increase**
	hybrid design with double pitch and identical heating surface area possible	less slagging => higher availability; fuel with more ash possible	✔		plant reliablility/ cost saving	**fuel costs reduction, planned and unplanned shutdown reduction, personnel costs and maintenance material reduction**
Additional CC heat surfaces	high heat transfere rate => lower cc outlet temperatur	higher performance => higher revenue	✔		higher revenue	**output increase**
	lower flue gas velocity	higher performance => higher revenue	✔		higher revenue	**output increase**
	higher load	higher performance => higher revenue	✔		higher revenue	**output increase**
	compact boiler space requirements	fast and easy erection => personnel costs saving	✔		cost saving	**personnel cost reduction**
	high erosion resistance	longer lifetime => lower maintenance costs		✔	plant reliability/ cost saving	**maintenance material, personnel, planned and unplanned shutdown reduction**
	fuel with higher LHV	lower fuel costs	✔		cost saving	**fuel cost reduction**
BFB nozzle grid for standard fuels	lower shutdown time	higher availability => lower maintenance costs	✔		cost saving/ personnel cost saving	**unplanned and planned shutdown red., personnel cost and maintenance material reduction**
	lower flue gas amount	higher performance => higher revenue		✔	higher revenue	**output increase**
	higher load possible	higher performance => higher revenue		✔	higher revenue	**output increase**
	less plugging	less unplanned shutdowns => higher availability => lower maintenance costs		✔	cost saving due to reduction of unplanned SD, purchasing success due to planning reliablility	**unpl. SD-day (50-100 kE); planned shutdown red., personnel cost and maintenance material reduction**
	improved primary air distribution => average bed temperature more evenly distributed	more evenly distributed bed temperature, lower Nox and CO emissions		✔	emission standards	-
	controlled and homogeneous combustion	lower fuel costs	✔		cost saving	**fuel cost reduction**
BFB nozzle grid for waste fuels	larger impurities in fuel possible	lower fuel costs	✔		cost saving	**fuel cost reduction**
	less unplanned shutdowns	higher availability => lower maintenance costs	✔		cost saving/ plant reliability	**unplanned shutdown red., personnel cost and maintenance material reduction**
	lower flue gas amount	higher performance => higher revenue	✔		revenue	**output increase**
	higher load possible	higher performance => higher revenue	✔		revenue	**output increase**
	longer lifetime	higher availability => lower maintenance costs	✔		plant reliability/ cost saving	**unplanned and planned shutdown red., personnel cost and maintenance material reduction**
	wires don´t plug the nozzles	less unplanned shutdowns => higher availability => lower maintenance costs		✔	plant reliability/ cost saving	-

Appendix 8: Table of values (3)

CFB nozzle grid for standard fuels	less shutdown time	higher availability => lower maintenance costs	✔		plant reliability/ cost saving	**planned shutdown reduction, maintenance material and personnel reduction**
	less lambda	less flue gas => higher load possible => higher revenue	✔		higher revenue	**output increase**
	lower flue gas amount	higher performance => higher revenue		✔	higher revenue	**output increase**
	higher load possible	higher performance => higher revenue		✔	higher revenue	**output increase**
	improved primary air distribution => average bed temperature more evenly distributed	more evenly distributed bed temperature, lower NOx and CO emissions		✔	emission standards	-
	less plugging	less unplanned shutdowns => higher availability => lower maintenance costs		✔	plant reliability/ cost saving	**unplanned shutdown, personnel cost, maintenance material reduction**
	controlled and homogeneous combustion	lower fuel costs		✔	cost saving	**fuel cost saving**
CFB nozzle grid for waste fuels	larger impurities in fuel possible	lower fuel costs	✔		cost saving	**fuel cost reduction**
	less shutdown time	higher availability => lower maintenance costs	✔		plant reliability/ cost saving	**planned shutdown, personnel cost and maintenance material reduction**
	less lambda	less flue gas => higher load possible => higher revenue	✔		higher revenue	**output increase**
	lower flue gas amount	higher performance => higher revenue	✔		higher revenue	**output increase**
	higher load possible	higher performance => higher revenue		✔	higher revenue	**output increase**
	design is avoiding cracks	longer lifetime => lower maintenance costs		✔	plant reliability/ cost saving	**planned shutdown, personnel cost and maintenance material reduction**
Vortex finder	less carry over	lower fuel costs		✔	cost saving	**fuel cost reduction**
	less erosion at convective heat surfaces	longer lifetime => lower maintenance costs	✔		plant reliability/ cost saving	**planned and unplanned shutdown red., maintenance material red., personnel costs red.**
	material is chosen according to the fuel used	longer lifetime => lower maintenance costs	✔		plant reliability/ cost saving	**planned and unplanned shutdown red., maintenance material red., personnel costs red.**
	efficiency can be increased by different options with no or low additional flue gas pressure	higher efficiency => higher revenue		✔	higher revenue	**output increase**
	longer lifetime	longer lifetime => lower maintenance costs		✔	plant reliability/ cost saving	**planned and unplanned shutdown red., maintenance material red., personnel costs red.**
Pneumatic fuel feeding system	less carry over of light fuels	lower fuel costs		✔	cost saving	**fuel cost reduction**
	higher bed temperatur	higher performance => higher revenue		✔	higher revenue	**output increase**
	more stable bed temperatur	higher performance => higher revenue		✔	higher revenue	**output increase**
	better combustion	higher performance => higher revenue		✔	higher revenue	**output increase**
	easy installation	faster erection => personnel costs saving		✔	cost saving	**personnel cost reduction**
	wider range of fuels (low calorific, low density) possible	lower fuel costs	✔		cost saving	**fuel cost reduction**
Advanced bed material recirculation	less fresh sand	lower investment in fresh sand	✔		cost saving	**costs for sand reduction**
	less agglomeration of bed material	higher availability => lower maintenance costs	✔		plant reliability/ cost saving	**unplanned shutdown, personnel cost, maintenance material reduction**
	optimal fraction size distribution of the bed material	lower emission/ less power for ID fan		✔	emission standards/ cost saving	**operating cost reduction**
	No additional mechanical parts in bed material extraction	lower maintenance costs	✔		plant reliability/ cost saving	**personnel cost and maintenance material reduction**
	less plugging	higher availability => lower maintenance costs	✔		plant reliability/ cost saving	**unplanned shutdown, personnel cost, maintenance material reduction**
Advanced SNCR Systems	perfectly adapted boiler	higher performance => higher revenue		✔	higher revenue	**output increase**
	reduced Nox emission	meet the emission standards		✔	emission standards	-
Advanced hybrid SNCR Systems	low Nox emission	meet the emission standards		✔	emission standards	-
	low investment for erection	lower personnel costs	✔		cost saving	**personnel cost reduction**
	low pressure loss	higher efficiency => higher revenue		✔	higher revenue	**output increase**
	only small changes at convective pass necessary for installation	fast installation => personnel costs saving		✔	cost saving	**personnel cost reduction**
	modification during regular shutdown possible	no additional shutdown needed => personnel costs saving		✔	cost saving	**personnel cost reduction**
	pressure part adaptions, like splitting the economizer or a bypass system, can be implemented easily	fast installation => personnel costs saving	✔		cost saving	**personnel cost reduction**
	no tail-end SCR necessary	lower costs of the plant	✔		cost saving	**investment cost reduction**
Upgrade 1st step: Concept development	Solution concept by expert	better solutions		✔		
Upgrade 2nd step: Feasability study	estimation of investment	good forecasting possible		✔		
Upgrade 3rd step: Realization	realization of Upgrade	high quality		✔		

Appendix 9: Emission Excel sheet (gas)

GAS	**IED 2010/75/EU Appendix V Part 2**			**BAT-AELs binding from 2021 yearly average[(1)] (daily average)**			**GAS**	**Efficiency needed**			**Efficiency needed**			**Efficiency needed**		
Natural Gas							Natural Gas	**Max. Case (Western Europe)**			**Average Case (Western Europe)**			**Min. Case (Eastern Europe)**		
	(existing plants appr. bef. 2013) valid after 1.1.2016			**Existing plant**				Existing Plant put into operation **after** 7.1.2014			Existing Plant put into operation **after** 7.1.2014			Existing Plant put into operation **after** 7.1.2014		
NOx (mg/Nm³) [6%O2]	50-100 MW_{th}	100-300 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}		50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}
	100	100	100	50 - 100 (85 - 110)			**NOx removal**	50%			25%			0%		
							to reach	50 mg/Nm³			75mg/Nm³			100 mg/Nm³		
							Measure:	**new SCR**	**new SCR**	**new SCR**	**flue gas recirculation**	**flue gas recirculation**	**flue gas recirculation**	**no adaption needed**	**no adaption needed**	**no adaption needed**
							CAPEX Estimate: [k€]	**1000 - 3000**	**3000 - 6000**	**6000 - 9000**	**100 - 300**	**300 - 600**	**600 - 900**	-	-	-

Appendix 10: Emission Excel sheet (coal)

COAL	IED 2010/75/EU Appendix V Part 2			BAT-AELs binding from 2021 yearly average[1] (daily average)			COAL	Efficiency needed			Efficiency needed			Efficiency needed		
Coal, lignite and other solid fuels							Coal, lignite and other solid fuels	Max. Case (Western Europe)			Average Case (Western Europe)			Min. Case (Eastern Europe)		
(no biomass and no peat)	(existing plants appr. bef. 2013) valid after 1.1.2016			Existing plant				Existing Plant put into operation **after** 7.1.2014			Existing Plant put into operation **after** 7.1.2014			Existing Plant put into operation **after** 7.1.2014		
SO_2 (mg/Nm³) [6%O2]	50-100 MW_{th}	100-300 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}		50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}
	400	250	200	150 - 360 (170 - 400)	95 - 200 (135 - 220[12])	FB20 - 180 PC10 - 130 (FB25 - 165[13] PC50 - 220)	SO_2 removal	62,5%	62%	FB 90% PC 95%	36,25%	41%	FB 50% PC 65%	10%	20%	FB 10% PC 35%
							to reach [mg/Nm³]	150	95	FB 20/ PC 10	255	147,5	FB 100/ PC 70	360	200	FB 180/ PC 130
WET scrubber installed							Measure:	REA plus modul (KRP)	REA plus modul (KRP)	REA plus modul (KRP)	REA plus modul (KRP)	REA plus modul (KRP)	REA plus modul (KRP)	Absorber tuning (new spraying layer)	Absorber tuning (new spraying layer)	Absorber tuning (new spraying layer)
							CAPEX Estimate: [k€]	1000 - 2000	2000 - 3000	3000 - 4000	1000 - 2000	2000 - 3000	3000 - 4000	300 - 400	400 - 800	800 - 2000
DRY scrubber installed							Measure:	add. reactor + add. hydrator	add. reactor + add. hydrator	new FGD plant	add. reactor + add. hydrator	add. reactor + add. hydrator	new FGD plant	Reactor tuning + hydrator tuning	Reactor tuning + hydrator tuning	Reactor tuning + hydrator tuning
							CAPEX Estimate: [k€]	3000 - 4000	4000 - 6000	10000 - 30000	3000 - 4000	4000 - 6000	10000 - 30000	50 - 100	100 - 300	300 - 600
NOx (mg/Nm³) [6%O2]	50-100 MW_{th}	100-300 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}		50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}
	300	200	200	100 - 270[9] (165 - 330)	100 - 180[9] (155 - 210)	FB<85 - 150[6][9] PC65 - 150[9] (FB140 - 165[10] PC<85 - 165[11])	NOx removal	66,67%	50%	FB >57.5% PC 67.5%	38,33%	30%	FB 41,25%[6] PC 46,25%	10%	10%	FB 25%[6] PC 25%
							to reach [mg/Nm³]	100	100	FB <85/ PC 65	185	140	FB 117,5/ PC 107,5	270	180	FB 150/ PC 150
No SNCR installed							Measure:	Hybrid Solution (SNCR + Slip Cat.)	Hybrid Solution (SNCR + Slip Cat.)	Hybrid Solution (SNCR + Slip Cat.)	SNCR	SNCR	SNCR	flue gas recirculation	flue gas recirculation	flue gas recirculation
							CAPEX Estimate: [k€]	700 - 1300	1300 - 2250	2250 - 3200	300 - 400	400 - 600	600 - 800	100 - 300	300 - 600	600 - 900
SNCR installed							Measure:	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	Optimization of existing SCR	Optimization of existing SCR	Optimization of existing SCR
							CAPEX Estimate: [k€]	500 - 1000	1000 - 1750	1750 - 2500	500 - 1000	1000 - 1750	1750 - 2500	50 - 100	100 - 250	250 - 500
Dust (mg/Nm³) [6%O2]	50-100 MW_{th}	100-300 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}		50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}
	30	25	20	2 - 18 (4 - 22[14])	2 - 14 (4 - 22[15])	2 - 10[7] (3 - 11[16])	Dust removal	93,33%	92%	90%	66,67%	68%	70%	40%	44%	50%[7]
							to reach [mg/Nm³]	2	2	2	10	8	6	18	14	10
ESP installed							Measure:	add. bag house filter	add. bag house filter	add. bag house filter	add. bag house filter	add. bag house filter	add. bag house filter	add. filter chamber	add. filter chamber	add. filter chamber
							CAPEX Estimate: [k€]	1500 - 2500	2500 - 5000	5000 - 10000	1500 - 2500	2500 - 5000	5000 - 10000	1000 - 1500	1500 - 2500	2500 - 5000
Baghouse filter installed							Measure:	add. bag house filter	add. bag house filter	add. bag house filter	adaption of existing filter	adaption of existing filter	adaption of existing filter	adaption of existing filter	adaption of existing filter	adaption of existing filter
							CAPEX Estimate: [k€]	1500 - 2500	2500 - 5000	5000 - 10000	1000 - 1500	1500 - 2500	2500 - 5000	1000 - 1500	1500 - 2500	2500 - 5000

Appendix 11: Emission Excel sheet (biomass)

BIOMASS + Peat	**IED 2010/75/EU Appendix V Part 2** (existing plants appr. bef. 2013) valid after 1.1.2016			**BAT-AELs binding from 2021** yearly average[1] (daily average) Existing plant			**BIOMASS + Peat**	**Efficiency needed** Max. Case (Western Europe) Existing Plant put into operation **after** 7.1.2014			**Efficiency needed** Average Case (Western Europe) Existing Plant put into operation **after** 7.1.2014			**Efficiency needed** Min. Case (Eastern Europe) Existing Plant put into operation **after** 7.1.2014		
SO_2 (mg/Nm³) [6%O2]	50-100 MW_{th}	100-300 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}		50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}
	300[27][28][29]	300[27][28][29][30]	200[27][28][29][31]	15 - 100 (30 - 215)	<10 - 70[2] (<20 - 175[21])	<10 - 50[2] (<20 - 85[21])	**SO_2 removal**	95%	>96,67%	>95%	80,83%	>86,67%	>85%	66,67%	76,67%	75%
							to reach [mg/Nm³]	15	<10	<10	57,5	40	30	100	70	50
Boiler with ESP							Measure:	add. Turbo Sorp	add. Turbo Sorp	add. Turbo Sorp	limestone + bag house f.	limestone + bag house f.	limestone + bag house f.	limestone + bag house f.	limestone + bag house f.	limestone + bag house f.
							CAPEX Estimate: [k€]	2500 - 3500	3500 - 6000	6000 - 12000	1500 - 2500	2500 - 5000	5000 - 10000	1500 - 2500	2500 - 5000	5000 - 10000
Boiler with baghouse filter							Measure:	add. Turbo Sorp	add. Turbo Sorp	add. Turbo Sorp	add. limestone dosing	add. limestone dosing	add. limestone dosing	add. limestone dosing	add. limestone dosing	add. limestone dosing
							CAPEX Estimate: [k€]	2500 - 3500	3500 - 6000	6000 - 12000	1000 - 1500	1500 - 2500	2500 - 5000	1000 - 1500	1500 - 2500	2500 - 5000
NOx (mg/Nm³) [6%O2]	50-100 MW_{th}	100-300 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}		50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}
	300	250	200	70 - 225[3] (120 - 275[19])	50 - 180 (100 - 220)	40 - 150[8] (95 - 165[20])	**NOx removal**	76,67%	80%	80%	50,83%	54%	52,5%	25%	28%	25%[8]
							to reach [mg/Nm³]	70	50	40	147,5	115	95	225	180	150
No SNCR installed							Measure:	Hybrid Solution (SNCR + Slip Cat.)	Hybrid Solution (SNCR + Slip Cat.)	Hybrid Solution (SNCR + Slip Cat.)	SNCR	SNCR	SNCR	flue gas recirculation	flue gas recirculation	flue gas recirculation
							CAPEX Estimate: [k€]	700 - 1300	1300 - 2250	2250 - 3200	300 - 400	400 - 600	600 - 800	100 - 300	300 - 600	600 - 900
SNCR installed							Measure:	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	Optimization of existing SCR	Optimization of existing SCR	Optimization of existing SCR
							CAPEX Estimate: [k€]	500 - 1000	1000 - 1750	1750 - 2500	500 - 1000	1000 - 1750	1750 - 2500	50 - 100	100 - 250	250 - 500
Dust (mg/Nm³) [6%O_2]	50-100 MW_{th}	100-300 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}		50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}
	30	20	20	2 - 15 (2 - 22)	2 - 12 (2 - 18)	2 - 10 (2 - 16)	**Dust removal**	93,33%	90%	90%	71,67%	65%	70%	50%	40%	50%
							to reach [mg/Nm³]	2	2	2	8,5	7	6	15	12	10
ESP installed							Measure:	add. bag house filter	add. bag house filter	add. bag house filter	add. bag house filter	add. bag house filter	add. bag house filter	add. filter chamber	add. filter chamber	add. filter chamber
							CAPEX Estimate: [k€]	1500 - 2500	2500 - 5000	5000 - 10000	1500 - 2500	2500 - 5000	5000 - 10000	1000 - 1500	1500 - 2500	2500 - 5000
Baghouse filter installed							Measure:	add. bag house filter	add. bag house filter	add. bag house filter	adaption of existing filter	adaption of existing filter	adaption of existing filter	adaption of existing filter	adaption of existing filter	adaption of existing filter
							CAPEX Estimate: [k€]	1500 - 2500	2500 - 5000	5000 - 10000	1000 - 1500	1500 - 2500	2500 - 5000	1000 - 1500	1500 - 2500	2500 - 5000

Appendix 12: Emission Excel sheet (solid waste)

Solid Waste	IED 2010/75/EU Appendix V Part 2			**BAT-AELs binding from 2021** yearly average[1] (daily average)			Solid Waste	Efficiency needed Max. Case (Western Europe) Existing Plant put into operation **after** 7.1.2014			Efficiency needed Average Case (Western Europe) Existing Plant put into operation **after** 7.1.2014			Efficiency needed Min. Case (Eastern Europe) Existing Plant put into operation **after** 7.1.2014		
	(existing plants appr. bef. 2013) valid after 1.1.2016			Existing plant												
SO_2 (mg/Nm³) [6%O2]	50-100 MW_{th}	100-300 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}		50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}
	50	50	50	(10 - 40)[33]	(10 - 40)[33]	(10 - 40)[33]	SO_2 removal	80%	80%	80%	50%	50%	50%	20%	20%	20%
							to reach [mg/Nm³]	10	10	10	25	25	25	40	40	40
Boiler with ESP							Measure:	add. Turbo Sorp	add. Turbo Sorp	add. Turbo Sorp	limestone + bag house f.	limestone + bag house f.	limestone + bag house f.	limestone + bag house f.	limestone + bag house f.	limestone + bag house f.
							CAPEX Estimate: [k€]	2500 - 3500	3500 - 6000	6000 - 12000	1500 - 2500	2500 - 5000	5000 - 10000	1500 - 2500	2500 - 5000	5000 - 10000
Boiler with baghouse filter							Measure:	add. Turbo Sorp	add. Turbo Sorp	add. Turbo Sorp	add. limestone dosing	add. limestone dosing	add. limestone dosing	add. limestone dosing	add. limestone dosing	add. limestone dosing
							CAPEX Estimate: [k€]	2500 - 3500	3500 - 6000	6000 - 12000	1000 - 1500	1500 - 2500	2500 - 5000	1000 - 1500	1500 - 2500	2500 - 5000
NOx (mg/Nm³) [6%O2]	50-100 MW_{th}	100-300 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}		50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}
	200	200	200	(50-150[32][33])	(50-150[32][33])	(50-150[32][33])	NOx removal	75%	75%	75%	50%	50%	50%	25%	25%	25%
							to reach [mg/Nm³]	50	50	50	100	100	100	150	150	150
No SNCR installed							Measure:	Hybrid Solution (SNCR + Slip Cat.)	Hybrid Solution (SNCR + Slip Cat.)	Hybrid Solution (SNCR + Slip Cat.)	SNCR	SNCR	SNCR	flue gas recirculation	flue gas recirculation	flue gas recirculation
							CAPEX Estimate: [k€]	700 - 1300	1300 - 2250	2250 - 3200	300 - 400	400 - 600	600 - 800	100 - 300	300 - 600	600 - 900
SNCR installed							Measure:	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	add. new catalyst layer (SNCR+SCR)	Optimization of existing SCR	Optimization of existing SCR	Optimization of existing SCR
							CAPEX Estimate: [k€]	500 - 1000	1000 - 1750	1750 - 2500	500 - 1000	1000 - 1750	1750 - 2500	50 - 100	100 - 250	250 - 500
Dust (mg/Nm³) [6%O2]	50-100 MW_{th}	100-300 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}		50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}	50-100 MW_{th}	>100 MW_{th}	>300 MW_{th}
	10	10	10	(2 - 5)[34]	(2 - 5)[34]	(2 - 5)[34]	Dust removal	80%	80%	80%	65%	65%	65%	50%	50%	50%
							to reach [mg/Nm³]	2	2	2	3,5	3,5	3,5	5	5	5
ESP installed							Measure:	add. bag house filter	add. bag house filter	add. bag house filter	add. bag house filter	add. bag house filter	add. bag house filter	add. filter chamber	add. filter chamber	add. filter chamber
							CAPEX Estimate: [k€]	1500 - 2500	2500 - 5000	5000 - 10000	1500 - 2500	2500 - 5000	5000 - 10000	1000 - 1500	1500 - 2500	2500 - 5000
Baghouse filter installed							Measure:	add. bag house filter	add. bag house filter	add. bag house filter	adaption of existing filter	adaption of existing filter	adaption of existing filter	adaption of existing filter	adaption of existing filter	adaption of existing filter
							CAPEX Estimate: [k€]	1500 - 2500	2500 - 5000	5000 - 10000	1000 - 1500	1500 - 2500	2500 - 5000	1000 - 1500	1500 - 2500	2500 - 5000