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"Gli impatti economici e ambientali dell'imballaggio: il caso di un nuovo sistema automatizzato al Centro Logistico Würth"

"The economic and environmental impacts of packaging: the case of a new automated system at Würth Logistic Center"

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ABBREVIATIONS

ADP – Abiotic Depletion Potential

ADR - Accord Dangereuses Route

AP – Acidification Potential

CC – Climate Change

CCB – Corrugated Cardboard Box

CM – Centimeter

CPI – Consumer Price Index

DFC – Discounted Cash Flows

DIY – Do-It-Yourself

DPP – Discounted Payback Period

EP – Eutrophication Potential

HDPE – High Density Polyethylene

HTP – Human Toxicity Potential

IMF – International Monetary Fund

KG – Kilogram

KM – Kilometer

KWH – Kilowatt Hour

LCI - Life Cycle Inventory

LDPE - Low-Density Polyethylene

LLDPE - Linear Low-Density Polyethylene

MM – Millimeter

NPV – Net Present Value

PMF – Particulate Matter Formation

POCP – Photochemical Ozone Creation Potential

ROA – Return On Assets

ROE – Return On Equity

RORO – Roll-on/roll-off ship

ROS – Return on sales

WD – Working Days

WH – Working Hours

WTP – Willingness-To-Pay

INTRODUZIONE

La prima volta che ho avuto l'opportunità di entrare in contatto con la multinazionale Würth è stata durante l'esperienza Erasmus+ in Germania. Il corso di "Change Management" tenuto dalla Professoressa Susanne Wilpers dell'Hochuschule Heilbronn, Università in cui ho passato i 6 mesi di Erasmus e dove conseguentemente ho ottenuto la Double Degree, era articolato in 2 fasi: la prima era dedicata a lezioni frontali ma interattive per approfondire il tema del cambiamento e della sua gestione nei processi aziendali e in team, mentre la seconda era concentrata nello studio dei casi studio direttamente forniti dalla Würth a noi studenti del corso. Alla fine della prima fase del corso sono stati formati i team e dopo l'illustrazione dei casi studio, fatta direttamente dal management aziendale nella sede centrale di Künzelsau, i lavori sono stati assegnati in base alla composizione dei gruppi ed alle competenze dei rispettivi membri. Il mio team aveva la responsabilità di investigare il mercato delle start-up e suggerire all'azienda, in base al business model e alle opportunità future, alcune alternative su cui investire che sarebbero state un valore aggiunto per il business dell'azienda. Dopo mesi di lavoro con un team internazionale molto coeso e con l'aiuto della Professoressa Wilpers, abbiamo presentato le nostre soluzioni insieme agli altri partecipanti che avevano però compiti differenti. Il top management Würth si è rivelato molto soddisfatto del nostro lavoro riscontrando anche che avevano già iniziato a prendere contatti con alcune start-up che noi avevamo suggerito, sottolineando che le nostre ricerche erano perfettamente in linea con le loro intenzioni.

Viste le buone impressioni reciproche sono rimasto in buoni rapporti con l'azienda. Non potendo prolungare la mia permanenza in Germania, rientrai in Italia e la Würth con tutta la sua disponibilità mi diede la possibilità di svolgere la tesi su un caso aziendale molto interessante, che diventò poi l'oggetto di questa tesi. Come suggerisce il titolo, il tema è la valutazione economica ed ambientale dell'investimento in un apparato di macchinari per l'imballaggio automatico nel centro logistico di Capena, prima che questi venissero installati concretamente. Ho passato 3 mesi in azienda (da Luglio a Settembre 2019) a studiare il funzionamento del centro logistico e, con l'aiuto del mio supervisore e responsabile della logistica Dott. Harders Patrick, ho potuto capire a fondo le dinamiche di tutto il sistema che poi mi è stato utile per inquadrare quello che poteva essere l'impatto dei nuovi macchinari. Ho avuto l'opportunità di:

- Svolgere tutte le mansioni degli operatori nei vari reparti della struttura, a rotazione;
- Entrare in contatto con i manager e studiare insieme a loro il sistema le modifiche utili o propedeutiche per i nuovi macchinari;
- Condurre studi e misurazioni per valutare l'efficienza dei macchinari esistenti e l'impatto di quelli futuri;

- Assistere alla valutazione di altri investimenti discussi direttamente con i fornitori oltre che conoscere e lavorare insieme agli addetti all'area commerciale (fuori dall'interesse dello studio oggetto della tesi).

Quindi, l'obbiettivo del lavoro è quello di determinare quali fossero i vantaggi o gli svantaggi dell'investimento sotto un'ottica sia economica che ambientale, prima che i macchinari venissero installati. Ho deciso di procedere subito con l'analisi economica, passare a quella ambientale in un secondo momento per poi integrarle assieme.

Il lavoro è articolato in quattro capitoli.

Il primo capitolo è dedicato alla descrizione del centro logistico in generale, dei due sistemi di imballaggio automatico adottati nel corso del tempo e la descrizione del sistema con i nuovi macchinari. Poi ci sarà un accenno alle motivazioni che hanno portato l'azienda ad investire in quei macchinari e quali sono i risultati attesi.

Il secondo capitolo illustra l'analisi economica dell'investimento. Sarà presente la rivisitazione della letteratura riguardo la tecnica del Valore Attuale Netto, le considerazioni su ogni fattore critico studiato, l'analisi del Valore Attuale Netto vera e propria e la discussione dei risultati.

Il terzo capitolo inizia con la definizione della metodologia per l'analisi ambientale e continua con l'applicazione della stessa ad ogni fattore.

Il quarto ed ultimo capitolo invece comprende lo studio dei metodi di monetizzazione delle variabili ambientali ottenute nel terzo capitolo. Prosegue con la monetizzazione delle variabili e la conseguente integrazione dei risultati nell'analisi del Valore Attuale Netto insieme ai risultati della valutazione economica effettuata nel secondo capitolo.

Per concludere verranno presentate le impressioni generali riguardo l'investimento tenendo conto delle tecniche utilizzate per la valutazione.

INTRODUCTION

The first time I had the opportunity to get in touch with the multinational Würth was during my Erasmus+ experience in Germany. The "Change Management" course held by Professor Susanne Wilpers of the Hochuschule Heilbronn, University where I spent 6 months and where I subsequently obtained the Double Degree, was divided into 2 phases: the first was dedicated to frontal but interactive lessons to explore the theme of change and its management within the company and team processes, while the second was concentrated in resolving the case study directly provided by Würth to us, students of the course. After the illustration of case studies, made directly by the company management in the Künzelsau headquarters, works were assigned based on the groups' composition and the skills of each respective member. My team had the responsibility of investigating the start-up market and suggesting, based on the business model and future opportunities, some alternatives to invest in that would have been an added value for the Würth business. After months of working with a very cohesive international team and with the help of Professor Wilpers, we presented our solutions together with the other participants. The top management Würth was very satisfied with our work, also finding they had already started to get in contact with some start-ups that we had suggested, underlining that our research was perfectly in line with their intentions.

Given the positive mutual impressions, I kept positively in contact with the company. Not being able to extend my stay in Germany, I returned to Italy and Würth with great availability gave me the opportunity to carry out the thesis on a very interesting business case, which then became the subject of this thesis. As the title suggests, the theme is the economic and environmental assessment of the investment in an apparatus for automatic packaging machinery in the Capena logistics center, before they were placed. I spent 3 months within the company (from July to September 2019) studying the operation of the logistics center and, with the help of my supervisor and head of logistics Dr. Harders Patrick, I was able to fully understand the dynamics of the whole system. It was strongly useful to frame what the impact of the new machinery might have been. I had the opportunity to:

- Perform all the operators' tasks in the various departments;
- Get in touch with managers and study with them the system, useful or preparatory changes for new machinery;
- Conduct studies and measurements to evaluate the efficiency of existing machinery and the impact of future ones;
- Assist the evaluation of other investments discussed directly with suppliers as well as knowing and working together with the employees in the commercial area (out of the interest of the study covered by the thesis).

So, the goal of the thesis is to determine what the advantages or disadvantages of the investment were from both an economic and environmental point of view, before the machines were installed. I decided to proceed immediately with the economic analysis, move on to the environmental one and then integrate them together.

The work is divided into four chapters.

The first chapter is dedicated to the description about the logistics center, of the two automatic packaging systems adopted over time and of the system with the new machinery. Then, there will be a hint to the reasons led the company to invest in those machines and what the expected results are.

The second chapter illustrates the economic analysis of the investment. There will be a review of the literature regarding the Net Present Value technique, some considerations on each critical factor studied, the analysis of the actual Net Present Value and the discussion of the results.

The third chapter begins with the definition of the methodology of the environmental analysis and it continues with the application of the same to each factor.

The fourth and final chapter instead includes the study of the monetization methods of the environmental variables obtained in the third chapter. It continues with the monetization of the variables and the consequent integration of results in the NPV analysis together with the results of the economic evaluation carried out in the second chapter.

Finally, general impressions about the investment will be presented taking into account the techniques used for the evaluation.

For privacy and competitive reasons, throughout this work I will not mention any real name of company involved in the project.

CHAPTER 1 - A NEW PACKAGING SOLUTION AT WÜRTH

1.1 THE WÜRTH GROUP

The Würth Group is the world market leader in its core business, the sale of assembly and fastening materials. In Würth Line, the product range for craft and industry comprising over 125,000 products for more than 3,6 million customers: screws, screw accessories, anchors, tools, chemical-technical products and personal protection equipment. Instead, Allied Companies of the Würth Group, which either operate in business areas adjacent to the core business or in diversified business areas, round off the range by offering products for DIY stores, material for electrical installations, electronic components (e.g. circuit boards) as well as financial services.

Adolf Würth in 1945 founded his family business in Künzelsau as a little shop. The founder died at the age of 45, and his son Reinhold took him over in 1954 when the business had a turnover of around €80.000. At the beginning of 60's the company started becoming global and founding the first European societies. In '69 Würth arrived in USA and South Africa. It currently consists of over 400 companies in more than 80 countries and has over 77,000 employees on its payroll. Over 33,000 of these are permanently employed sales representatives. The Würth Group generated total sales of €13.6 billion in the business year 2018 (Adolf Würth GmbH & Co. KG, 2019).

During the internationalization of the company, Reinhold decided that the Würth must be present also in Italy. In 1963 the first headquarters was launched in Terlano, that was moved to Egna in 2002. In the international landscaped of the company, Würth Italy is the biggest foreign society. Now, there are 2 headquarters and 3 logistic centers spread around the Italian territory. In Egna (Bolzano) and Capena (Rome) there are the headquarters and a logistic center, instead in Crespellano (Bologna) only the logistic center is present. There are more than 150 pick up shops scattered all over Italy to satisfy the immediate needs of customers (Würth Italy Srl, 2019).

1.2 THE LOGISTIC CENTER IN CAPENA

The logistic center based in Capena has been the second headquarters run by the company and it is currently the core sorting facility in Italy. It has been renovated in 1999 and extended in 2005, reaching a surface of 41.000 m^2: 30.000 assigned to magazines and 11.000 to offices and services. It has 2 main warehouses: the warehouse "A" and "X". The "A" captures the most common and standard products treated by the center, whereas in "X" are processed more particular items in terms of size, shape and heaviness.

Capena branch has around 24.000 articles in stock, that are two times the range treated by the headquarters based in Egna. It serves both pick up shops and customers that buy online, privately and through salespersons, shipping around

3.240 packages and pallets per day (in 2018). Pick up shops represent almost 15%, instead customers constitute the major part, 85% of total products ordered. More than 90% of deliveries are combined and shipped one-time to recipients with the goal of avoiding redundant shipments and decreasing significantly costs of transportation (Harders, Logistica Capena WYN - G, 2019).

Currently, the logistic center has 153 employees: 43 of them are contract workers and 9 are interns. There is a bearing of 28,1% temporary workers on the total that will remain nearly the same over the months. The introduction of the "Decree Law no. 87/2018, converted in Law no. 96/2018" has been restricting the flexibility of hiring temporary workers, so the company cannot freely adjust the number of employees according to seasonality and necessities.

The organizational structure of the logistic center in Capena is divided by a functional criterion, as represented in figure 1. On the top, there is a logistic managing director followed by an assistant. Moreover, there are 5 managers assigned respectively to 5 different macro functions: inbounds, returns, picking, outbound, X-warehouse of goods and controlling. On the lower level, there are different team leaders devoted to more specified tasks and to supervise more closely the manpower and operative activities. The work done by the controlling office is essential: it is responsible to supervise the entire production process, breaking it down in case of problems and identifying the causes (that is possible thanks to SAP and KNAPP systems, which keep track of packages, products, working stations, provisions and everything that regards the production).

Figure 1 - Top levels organizational chart

The operational nucleus is composed by several activities, each one linked to its team leader and manager:

- Truck unloading and goods allocation of warehouse “A” and “X”, together with the replenishment, are activities linked to team leaders under the Inbound manager;
- Returns administration and goods processing are associated to returns team leader and manager;
- Products picking (in warehouse A) is ascribable to picking team leaders and manager.
- Order start or cardboard forming, control and clearing of packages, filling materials placement, packing and order replacing, palletizing and X-

warehouse management are activities supervised by the outbound and X-warehouse team leader and manager.

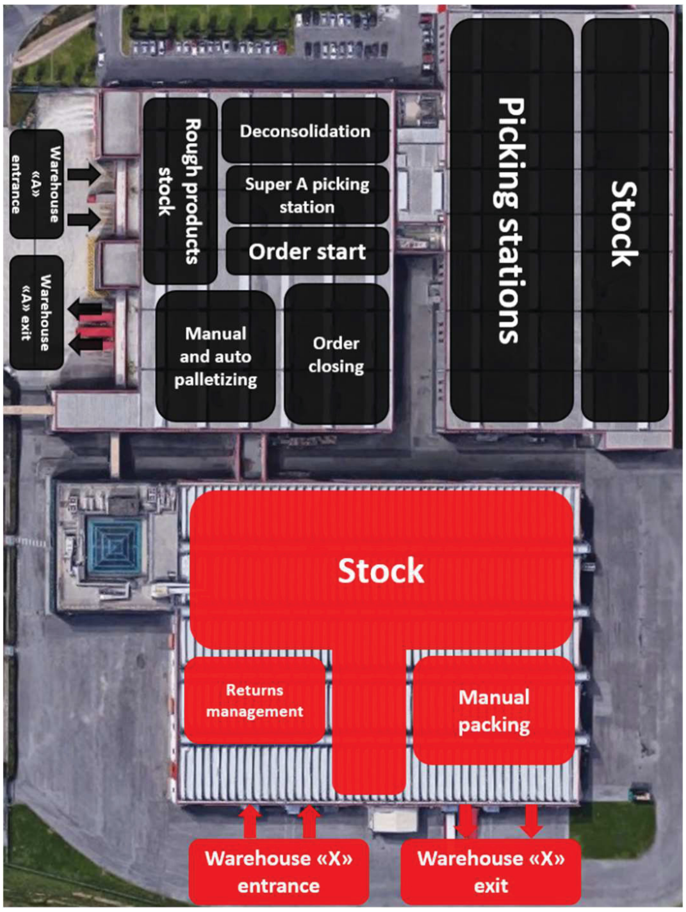
There are workers assigned to each activity according to characteristics, production requirements and production levels, that from now on must be more stable due to the reasons explained before.

To introduce the purpose of the machines is essential having a bird's eye view of the whole process. For this reason, I am going to explain briefly how the building is structured and the most important activities made in it. The logistic center is mainly divided into two big areas: the warehouse "A" depicted in black and the warehouse "X" depicted in red in figure 2. The first one is almost completely automatic and covered by 3,5 km of conveyor belt, where smaller and standard products are handled by regular processes. Instead, warehouse "X" is primarily devoted to managing heavy, outsized and peculiar products (Harders, Logistica Capena WYN - G, 2019).

Following the goods flow throughout buildings, I want to explain roughly each step underwent by products. As obvious, merchandise arrive in warehouse "A" entrances carried by supplier with trucks. They are stored temporarily in proximity of the entrance and a priority is assigned automatically to each pallet, package or product according to several parameters: class (from "F" to "A"; it indicates the sales volume), stock level, number of orders requiring the item, expiry date, volume and space. Basing on the priority, wares are moved to the deconsolidation section where are worked to be ready for the picking or, in case there is not urgency, to be stored. Outputs of deconsolidation stations could be a pallet or a cardboard with materials ready to be shipped and/or a pallet with no decomposed packages to be placed in the stock area.

At the same time, the order starts with the box forming machine that works depending on the orders engendered. The empty box starts from there its trip on the conveyor belt with a code associated to the order. The code is read by photocells placed along the belt, which establish when the box must be diverted to the stations. The first possible stop of the empty box is the "super A" station where are placed high demanded products (it is close to the decomposition section, order start and order closing to reduce the distance covered). Otherwise, it goes to the 42 picking stations: each station has a range of products and the box stops according to articles needed to complete the order. In these stations, operators arrange products according to items code and quantity indicated in the work sheet left inside the box. Once a box has been filled with all articles ordered, it moves to the closing section. Here, there are several activities: the clearing stations check and fix possible mistakes or problems originated beforehand; the filling materials stations fill boxes with paper and plastic; the manual packing stations are dedicated to smaller orders or to satisfy particular customers necessities; and packets closing. To avoid the interruption of the whole process in case of machine breaks or work overload, there are two identical lines for both orders start and closing. After the closure, box goes to manual or auto palletizing terminals depending on the destination (key accounts, customers or pick up shops), the characteristics (ADR materials, chemicals, dimensions) and the packaging. Once in pallets, packages are ready to be shipped and charged in trucks.

Figure 2 – The layout of Capena logistic center



Regarding warehouse “X”, as mentioned before, it is not as automatic as the other one because there pass through different types of materials that require ad hoc management (such as power tools, working equipment, chemicals in big format). So, everything that does not fit the package sizes used in warehouse “A” is managed in warehouse “X”. There, an operator stows temporarily inbound goods in the entrance vicinity (a decay section is not required for products characteristics and because they are often shipped with the original packaging). Afterwards, products are placed in a designated area and two categories of location exist: the ground floor (where operators pick up items to pack) and higher levels for reserves. In the manual packing area there is a team of men that collects and crates manually, having several sizes of cardboard available (Cerrone, 2019). At the beginning of each shift, the warehouse team leader assigns to each barcode reader an appropriate number of picks according to operators’ skills and being aware to unify similar and/or close products (Nappi, 2019).

In “X” there is also an area dedicated to returns, where products come back from customers for several reasons, categorized in 6 classes: commercial (item ordered wrongly by the customer, item not corresponding the request, courtesy returns, quantity overload, item not ordered or price too high), administrative (wrong invoicing or wrong information in the invoice), storage courier (goods rejected), logistic (item shipped wrongly, item or delivery damaged, delivery times too long, goods invoiced but not shipped or wares lost by the courier), other (returns directly from the customer, right of withdrawal and unknown) and product quality (Masciullo, 2019). Depending on the status, for returns exist three reallocations: the item is in good status so it can be repacked and sold again; the expiry date is close or the conditions are not optimal so the product can be sold in promotion or in the eBay channel as regenerated, otherwise it will be thrown away or used internally (Clemenzi, 2019).

1.3 THE ORIGINAL SYSTEM: "ALFA"

From now on, I am going to use "Alfa" to mention the original system or the group of machines that Würth has in its automatic packaging line. The manufacturer is a French company based in Dijon. They had run the business in the 60's as packaging machine manufacturer focused mainly on the wine industry. In the 80's they started diversifying in packaging machines and small automated order preparation systems. Afterwards, the company continued to specialize in the area of engineering and the integration of complex warehouse automation. It enlarged its business in Europe with an expanded partner network and customers. They work with 3 different brands, each of them is specialized in offering customized solutions for different needs. Currently, it has 590 employees, a turnover of 85 million euro and solutions spread in 40 countries[1].

[1] Source: Company website.

The Alfa system used by Würth is composed by 3 different types of machines, described in the table 1. The first one is placed in the order start section, the other two in the closing section.

Table 1 – Alfa machines specifics

Machine	Description	Max throughput (Units/h)	Power (Kw)
N° 2 Case erectors and plastic wrap appliers	#1: 500x300x125mm. #2: 500x300x250mm. Integrated glue generator with manual refilling.	720	16
N° 2 Shrink tunnels	Thermal fusion at 400 °C	420	43
N° 2 Lidding machines	Integrated glue generator with manual refilling.	240	5

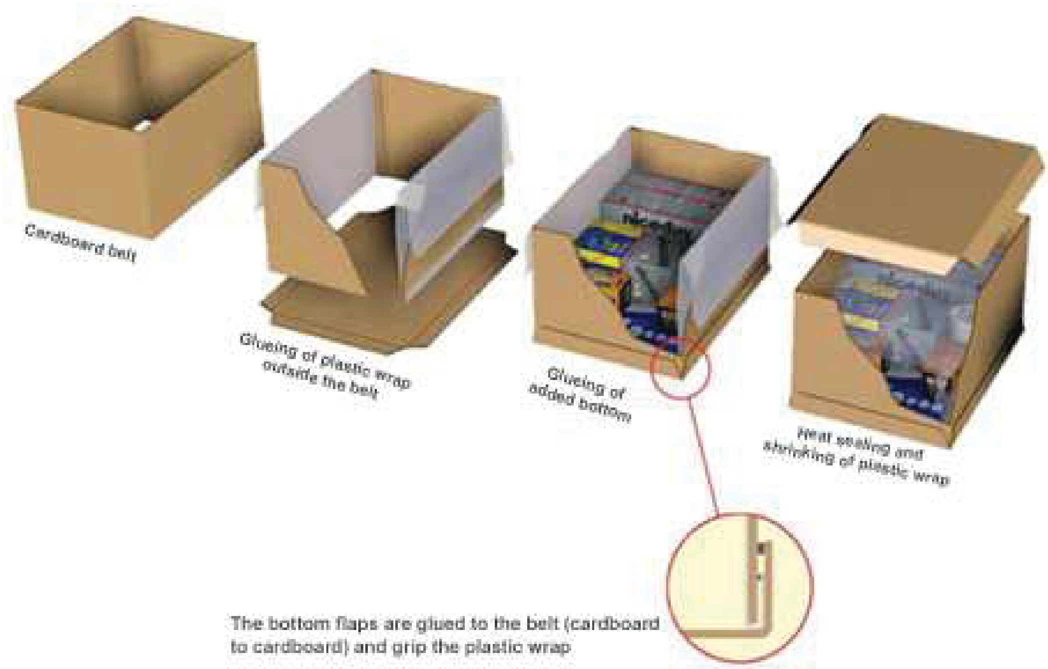
Source: elaborated of products technical files.

The sequence of processes (illustrated in figure 3) is the following:

1. Cardboard belt forming;
2. Plastic wraps and lid applying;

3. Products placing;
4. Plastic shrinking;
5. Box closing.

Figure 3 - Alfa packaging production



Source: Company website

The first step is done by the case erector, which forms the cardboard belt (depending on the order, it could be 125 mm or 250 mm high). Then, the cardboard belt pass under the plastic wrap applier. Here, two plastic films and a lid on the bottom are applied to the cardboard belt. The fastening of these parts is done by hot glue.

In the picking sections, operators fill the boxes with products. Once the box is filled with all the products ordered by the customer, a protective cardboard is placed over them (that is an expedient introduced by the management to reinforce the protection). Then, it passes to the shrink tunnel where the plastic wrap is heated under 400 °C thermo fusion, for sticking it to the contents. This process keeps the contents stable and safe. The final step is when another lid is applied and glued on the top of the cardboard.

1.4 THE INTERMEDIATE SOLUTION

Some issues with Alfa system forced the logistic managers to adopt an intermediate solution. The problems Würth was facing are the following:

- The plastic wrap could not guarantee enough stability to products and it broke easily;
- Some products, such as chemical products, must not undergo the thermal fusion for security reasons (high temperatures could cause products alteration or little explosions). So, the entire line needed to be stopped and an operator was appointed to treat the order manually;
- Every time products on the top of the pack were wrapped with plastic, it stuck to the plastic of the cardboard and customers received ruined products;
- Risk of fires during the thermal fusion.

In order to eliminate these problems, managers have drawn an alternative system to replace the plastic wrap as products safeguard and consequently to remove the shrink tunnel machine. They substitute filling materials for plastic wrap, with a massive usage of them to compensate.

This alternative replaces the shrink tunnel with a manual station directed by an operator, who fills empty packs with four different types of filling materials: recycled paper in two forms other than air pillows and bubble wraps.

So, the sequence becomes the following:

1. Cardboard belt forming;
2. Lid applying;
3. Products placing;
4. Filling materials placing;
5. Box closing.

The first step remains unchanged: the case erector forms the cardboard belt and a lid on the bottom is applied to it. The fastening of the lid is still done by hot glue. In this intermediate solution, the plastic wrap applying step is skipped. Maintenance specialists have modified the mechanic process of machines to avoid the plastic application (Stefani, Technical information about the machines, 2019).

Like the original system, operators in picking stations fill boxes with products. Later, the box does not pass under the shrink tunnel as before. It goes in a dedicated station where another operator lays filling materials (such as bubble wrap, air pillows and paper) whenever the contents is not stable enough. The usage of filling materials is massive because it must guarantee safety and stability to products inside. Workers are trained to place materials correctly, and in front of the station there is an illustration of the best practice (see figure 4).

The final step still consists in the lid applying on the top of the cardboard.

Figure 4 – Filling materials placement: the best practice

1.5 THE INVESTMENT: "BETA"

Even if the intermediate solution solved problems related to the plastic wrap process and output, it is not the optimal one and other issues persist:

- Massive consumption of plastic and paper because, despite expedients and optimization of the process, there is a lot of empty space in some cartons. Therefore, customers need to get rid of too much filling materials;
- Packaging fragility due to the empty space. It entails the collapse of the cartons placed on the bottom of the pallet;
- About the 10% of returns is attributable to logistic, and a portion is due to the poor quality of packages that arrive damaged to customers.

In addition, removing the shrink tunnel and working with a large usage of filling materials is costly. There is an increase in costs, even if without the machine there is a significant cost-saving of 123.000€ (costs bore in 2016), because the intermediate solution has consumed 148.000€ in 2018 (Harders, Budget new packaging line IT-W Capena, 2018).

The manufacturer of the Beta system is another France company. It operates since 1982 as a designer-manufacturer of automated industrial equipment in many business sectors. Since 2000, it specialized in packaging solutions for order fulfillment and distribution. In August 2015 an American company present globally, bought the manufacturer of Beta machines. Therefore, thanks to the takeover, the company is represented worldwide[2].

[2] Source: Company website

The two remaining Alfa machines, the case erector and the lidding machines, will be replaced with another 2 types of machines (see table 2). The machines are not already installed but the manufacturer already gave to Würth all the technical specifics.

Table 2 - Beta machines specifics

Machine	Description	Max throughput (Units/h)	Power (Kw)
N° 2 Tray Erector	#1 format 400x300mm* Integrated glue generator with automatic refilling.	900	7
	#2 format 500x300mm Integrated glue generator with automatic refilling.	900	10
N° 2 Lidding machines	#3 format 400x300mm* Integrated glue generator with automatic refilling.	840	11
	#4 format 500x300mm Integrated glue generator with automatic refilling.	720	11

*are able to process also the bigger format 500x300mm in case of necessity.

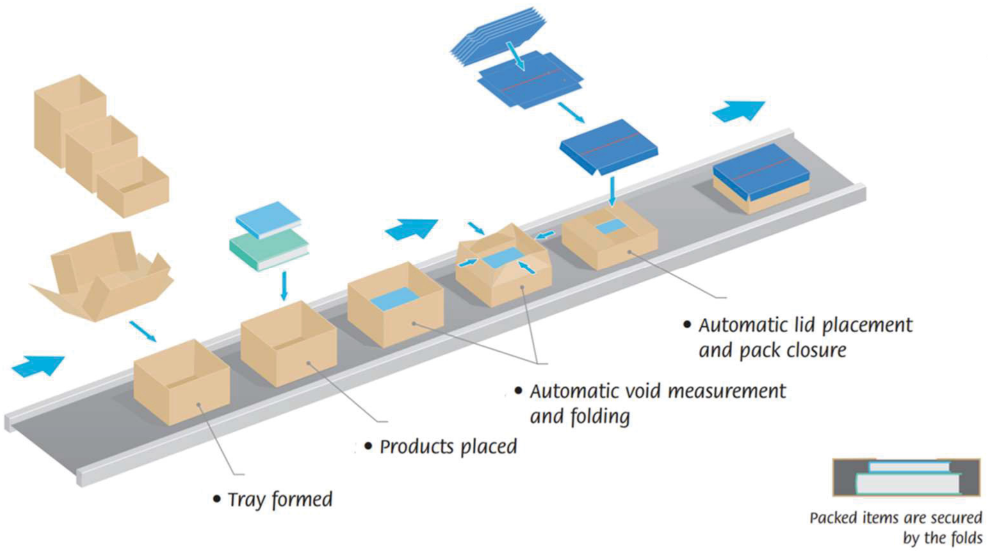
Source: elaborated of technical files made by Beta

The processes sequence (illustrated in figure 5) with the new system will become the following:

1. Tray forming;

2. Products placing;
3. Automatic void measurement and folding;
4. Box closing.

Figure 5 - Beta packaging production



Source: Company website

The two erectors form the tray through applying the glue and folding the cardboard, one smaller (400x300mm) and another one bigger (500x300). The manager introduced a redundancy expedient: the machine #1 can be set to make also the greater format, in case the need to stop #2 occurs for any reason (Harders, First visit in Würth - The introduction to the case, 2019). Ten years is the time the company depreciate the expense in its financial statement and 13 years is the period old machines (same function and type) have been working in the logistic center of Capena. Therefore, considering a more aggressive technological progress, machines will become obsolete even sooner: their lifecycle is set to 12 years for the overall study.

Afterwards, picking operators place products inside the box keeping them at the lowest level as possible. Eventually, if there is too much empty space another operator fills it with paper or plastic bubble like in the intermediate solution. Then, the lidding machine automatically measures the void and folds the cardboard. The same machine places a lid and close the pack.

This system strengthens the boxes and reduces the consumption of filling materials through preventing too much empty space in packs.

1.6 KEY DRIVERS OF THE INVESTMENT

The major reasons that led Würth to invest in a new packaging system are focused on customers and their satisfaction. In fact, what turned on the first light in the managers' head, were returns and complaints made by customers and shops for damaged packs and products. Furthermore, the problem was clearly visible because pallets, that remain for weeks or months in the warehouse, collapse frequently (Harders, First visit in Würth - The introduction to the case, 2019). These events have occurred too much often. After several attempts to remedy with expedients, from the protective cardboard inside packs to the massive usage of filling materials, the company decided to rethink the overall system in order to solve problems permanently, even with an eye on the future.

Once they figured out the need of change, other variables have intervened for the selection of the preferred option. In addition to the bad quality of packaging, further malfunctions needed to be spotted and fixed. Those malfunctions concern processes, consumptions and consequently also the output.

The first signal from the customers side were returns: they count 3% of turnover, and through interviews and questionnaires came out that 10% of them is attributable to logistic failures.

Additionally, the following disruptions and problems supported the decision:

- The plastic wrap system to secure the contents does not work properly and, when there are dangerous products on the line, it slows down the process. It is also accountable of fires happened several times since the system has been installed.

  Furthermore, its costs are high. Indeed in 2016: on average 30.000 Kg of plastic consumption for around 51.000€ (plastic wrap film), around 7.900 Kg of paper consumption for 35.000€ (protective cardboard), around 9.500€ for the electricity that is important mainly in terms of environment because Würth pays a very low price for it; around 27.500€ for blades substitution for film cutting and maintenance works in general. A total of 123.000€ in 2016.

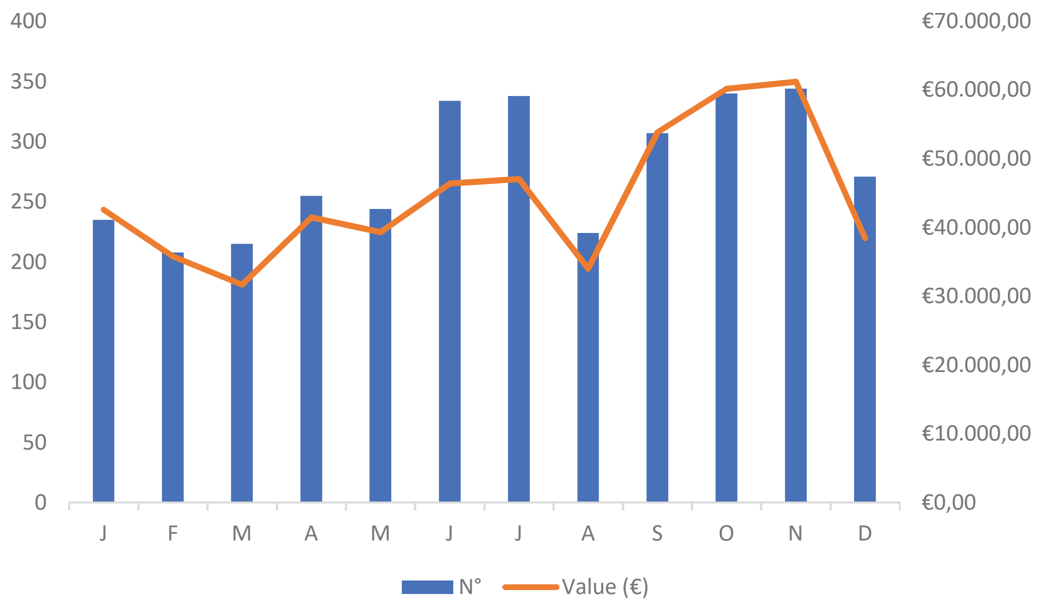
- The intermediate solution safeguards products but it does not solve all problems such as the packaging fragility, material consumption and costs. Indeed, it cost even more: in 2018 were used around 5.800 Kg of plastic for 53.000€ and around 9.900 Kg of paper for 23.000€. With 2 additional workers (1 per line) at the cost of 72.000€, a total of around 148.000€ was spent in 2018.
- Only a single supplier can guarantee the quality standards of the cardboard for the original system. Instead, with new technologies more suppliers will disclose to Würth. So, competition helps the company to subscribe more favorable contracts;
- More robust packaging solution opens the possibility to reduce thickness, quality and consequently costs of the cardboard, that otherwise is impossible.

1.7 EXPECTED OUTCOMES

As mentioned in the previous paragraph, the essential objective of the company is to improve the overall service granted to its customers, improving the packs resilience and reducing returns attributable to packaging and logistic disruptions. To reach the customer satisfaction the logistic center needs to reinvent the overall packaging line, taking the opportunity to perfect existing flaws whenever possible. Therefore, the expected outcomes in detail are:

- Decreasing the returns ascribable to logistic caused by damaged products and/or packages. In 2018, the number of monthly returns for those reasons are represented in figure 5. During the overall year, these returns were 3.315 and counted more than 500.000€. The bad quality of packaging is not the single cause because also couriers are accountable to ruin contents and packages;

Chart 1– Returns from customers: product/delivery damaged



Source: elaborated of statistical records made by Masciullo Claudio

- Increasing pack sturdiness that is directly linked to reach the previous goal;

- Filling materials elimination or at least a significant reduction. It entails a decrease in costs and material consumption for more sustainable packaging. In 2018 were used approximately: 9.900 Kg of paper for 23.000 € and 5.800 Kg of plastic for 53.000€;
- Lowering the number of cardboards used for the same amount of orders;
- Diminishing packages volume up to remove one pallet to ship per day;
- Increasing supplier competitions and having a larger number of cardboard suppliers through the usage of up-to-date material: it entails less dependence and lower costs. The company has relied on a single supplier until now, with all related risks;
- Reducing the cardboard thickness and quality in order to decrease procurement costs.

CHAPTER 2 - THE ECONOMIC ASSESSMENT

From now on, I am going to consider and compare only the intermediate solution to the new system. The choice is due to incompleteness of data regarding the old system and because the difference made by the investment must be measured in comparison to the current process: at this point the previous one is passed.

2.1 LITERATURE REVIEW

Because globalization and technologies are broadening companies' horizons, some of them are able to take advantage of every opportunity also due to the crisis. To avoid being left out from the competition, firms need to improve the business process keeping the delivery of customer's value as much high as possible. So, the value chain is crucial because it includes the major functions that boost the value of products and services evaluated by customers. For these reasons the company needs to coordinate its business process to span the value chain functions, which are: research and development, product design, manufacturing, marketing, distribution and customer service (Brewer, Garrison, & Noreen, 2010). Customers are the core of Würth vision, which mentions these words: "The Würth Group is one of the worldwide biggest suppliers of assembly and connecting technology to craft and industry. What spurs us on? We love selling. Satisfying our customers is not enough. We want to inspire them - by offering ideas that make their business progress. Becoming the number 1 in the eyes of our customers as the best sales team" (Adolf Würth GmbH & Co. KG, 2019). The object of this analysis regards important parts of the value chain: distribution and customer service.

One of the most important and recent practice to enhance and to optimize the value chain is the lean management, which should bring quantitative and qualitative improvements. The key principles of the lean management are the following: removal of waste, continuous improvement and the involvement of all organizational levels. Crucial to achieve these goals is: defining the value from the customer's point of view, defining also its flow, let the flow moves quickly, pulling it and searching for perfection. At the same time, the company should distinguish which activities add value and it should also allocate optimally the resources to them, standardizing processes as much as possible and leaving space to the learning process (Womack & Jones, 2003).

As mentioned before, one of the key principles is to remove waste. But it does not mean to diminish independently costs through reducing hours per worker, space, stock, time to develop products, production etc. It means eliminating the seven "Muda" as long as they do not add value to customers such as corrections, overproduction, movements of materials and people, waits and production not aligned to customer expectations (Napoli & Tonchia, 2011). The Six Sigma method is used by international and leader businesses to improve their own process basing on customers' feedback and fact-based gathering data. Its goal is leading to exploit all opportunities and collecting zero defects throughout each step of the value chain.

The most effective and common framework to guide it, is known as DMAIC (Define-Measure-Analyze-Improve-Control). The Define stage is devoted to understanding the current situation of the business process and define what is not aligned with customer requirements. The Measure stage consist of gathering information about the existing system and to lead the new project to solve most important problems. During the Analyze stage, the firm should identify problems sources and non-value-added activities. Finally, when the preliminary analysis is finished it is time to implement solutions and to eliminate malfunctions spotted before: that is the Improve stage. After the implementation, the Control stage is devoted to supervising the new solutions and to improve them over time searching for perfection constantly (Brewer, Garrison, & Noreen, 2010). Würth adopted this method in implementing the new solution at the logistic center in Capena. Firstly, it defined how it was supplying the service and the customer requirements: managers recognized the system is not providing enough sturdy packages and recipients needs to get rid of too much material, in other words it did not provide added value. Afterwards, they attempted to characterize and quantify the customers dissatisfaction through questionnaire and surveys included in returns requests. It has helped them to identify how much harmful it was to the company. Once they figured out the non-value-added activities and unsatisfactory outputs, they started looking for alternatives to solve the problems. Now, there is the Improve stage with the gradual implementation of machines followed by the Control stage and the continuous improvement.

2.2 CAPITAL BUDGETING FUNDAMENTALS

Capital budgeting consists of evaluating decisions made by organizations on allocating resources to investments of a significant size. For instance, they include investments for: cost reduction, expansion to increase production capacity and sales, equipment selection, lease or buy and equipment replacement. When you should decide whether a project is acceptable or not, there is a so-called screening decision. Instead, when you should select among several acceptable projects which is the best one, there is the so-called preference decision (Brewer, Garrison, & Noreen, 2010).

This economic assessment will involve a screening decision of an equipment replacement: the company has already verified the necessity to replace the old equipment and it has selected also which one to buy, so the analysis will evaluate just the profitability and the financial feasibility of the decision.

Capital investments have a common characteristic: the amount of money to purchase a capital item must be paid out immediately or in a short period of time (at least shorter than the capital item life), whereas benefits from it accrue over time. So, recognizing the importance of the time value of money is crucial during the evaluation of capital budgeting decision because a dollar today is worth more than a dollar tomorrow or a year from now. The reason behind the concept are based on opportunity costs because you can simply put a dollar in a bank today and receive more than it one year later, without considering any risk (Ehmke & Boehlje, 2007). In capital budgeting calculation I will always discount incremental cash flows, not earnings because they are not real money available to dispose of. The incremental cash flows are modifications in the company cash flows that arose directly from accepting the project, so from the investment itself. To identify what incremental cash flows are and considering only the relevant costs of projects, is fundamental categorizing costs and effects in this way (Ross, Westerfield, & Jaffe, 2019):

- Sunk cost: it is a cost already occurred independently of project acceptance or rejection. Therefore, these costs exist even if the project will be rejected and they do not determine increments in cash flows;
- Opportunity cost: is the loss of a potential benefit that occurs when a project is selected over another. It determines a change in cash flow and it must be carefully taken into account during the evaluation;
- Side effects: such as cannibalization or synergy. Cannibalization effects occur when, for example, a new product steal the sales to another one that already exists. Instead, synergy effects come up when a new project increases the cash flows of existing projects.

2.3 DISCOUNTED PAYBACK PERIOD

The Discounted Payback Period (DPP) is the evolution of the Payback Period, one of the most common and simple method used in capital budgeting to evaluate investments. It measures the amount of years the discounted value of expected cash flows takes to be equal to the initial outlay of the investment (MediaWiki, 2018). Like every method used in capital budgeting decisions, it has advantages and disadvantages that are summarized in table 3 (Ross, Westerfield, & Jaffe, 2019).

Table 3 – DPP pros and cons

PRO	CONS
Simple to understand and easy to compute	It ignores all cash flows beyond the cutoff date
It considers the time value of money and the project riskiness	Arbitrary estimate of the discount rate
Firms with shortage of cash can easily select the investment that paybacks the initial outlay sooner	It does not provide any clear indication if the investment increments the firm value

I decided to evaluate the investment by using the DPP method first. It provides an indication about the time required to recover the initial expense. In other words, it suggests how many years the machines should work regularly at operating speed and with the assumptions supposed, to guarantee the recovery of the investment. I have preferred the DPP rather than the simple payback period because the investment object of the analysis will take several years to recover the initial expense, so the time value of money plays an important role and it alters the assessment. The interest rates I used to discount cash flows are equal to the NPV discount rates, and I will discuss the process of selection in section 2.4.1.

2.3.1 Scenario 1: the DPP best-case

Scenario 1 considers assumptions made for best and worst cases analyzed deeply in section 2.4.2 and a discount rate equal to 5,16%. The reasons behind the choice of the discount rate are discussed in section 2.4.1. Synthetically, it is a ratio between "Net Income" and "Total Assets" of the company for a period of 5 years and it reflects the profitability of its operating activities.

As can be seen from chart 2, the Discounted Payback Period best-case is six years and seven months. Considering the machines' lifecycle based on assumptions made in section 1.5, the DPP is almost the half of that: it means the company starts to benefit from the investment relatively soon, and it enjoys the benefits for six years. To sum up, the analysis lead to a good outcome. Especially if the company considers also the factors mentioned in paragraph 2.4.3, its orientation towards customers, the supposed improvement in terms of environmental impacts. Under the general perspective the interpretation is sensibly good and the real effect of the investment is even greater and more beneficial compared to results showed by this economic analysis.

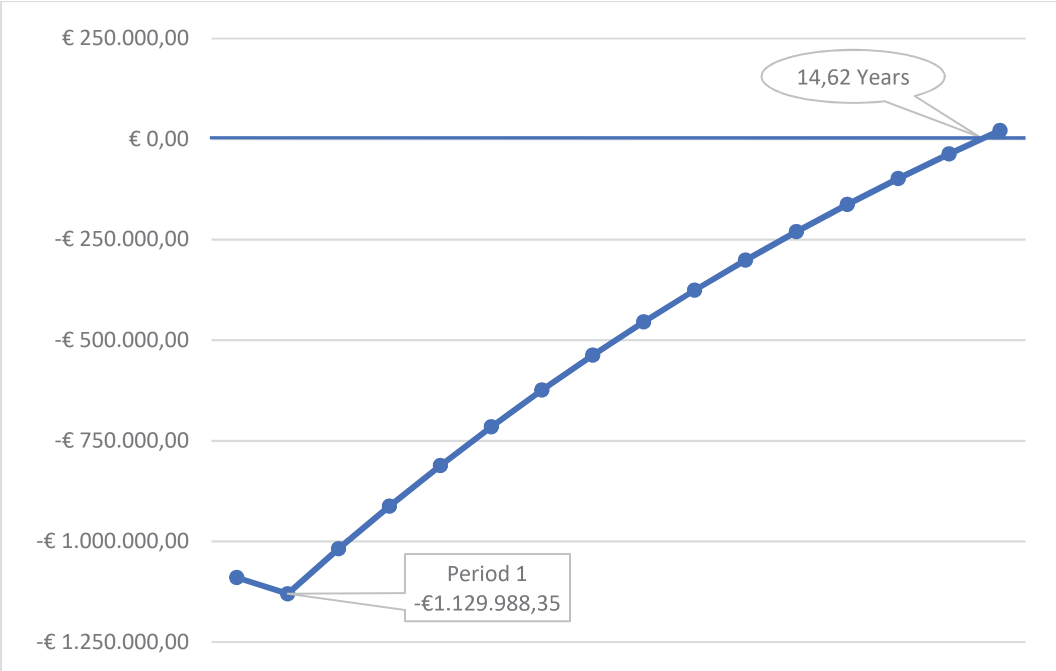
Anyway, regarding the cardboard supply (that has the most important impact on incremental cash flows), the management already have decided to use during the first phase the most expensive cardboard supply for prudence, and only after the process is got up to speed attempts with lower quality cardboard will be made. The phase of trial with the most expensive cardboard will take three months at least. So, results should be a bit worse than the results showed by the best-case because the latter one considers cheaper cardboard supply since the first month.

Chart 2– Discounted Payback Period: best-case scenario 1

2.3.2 Scenario 1: the DPP worst-case

Instead with the worst-case assumptions, clarified deeply in section 2.4.2, the situation gets worse and the discounted payback period rises up to more than fourteen years (see chart 3). The first year has an important impact because the incremental cash flow is negative and the discount factor is the highest among the others, that instead discounts more positive incremental cash flows of the following years, when the company starts to benefit from the investment. So, money lost during the first year is worth more than savings in future periods. Positive incremental cash flows are not sufficiently large to compensate the capital spending and the implementation phase (first year) for ensuring an acceptable time of recovery from the investment. Under these conditions the new system reveals as a bad decision, even considering the factors not involved in the analysis as explained in section 2.4.3.

Chart 3 – Discounted Payback Period: worst-case scenario 1



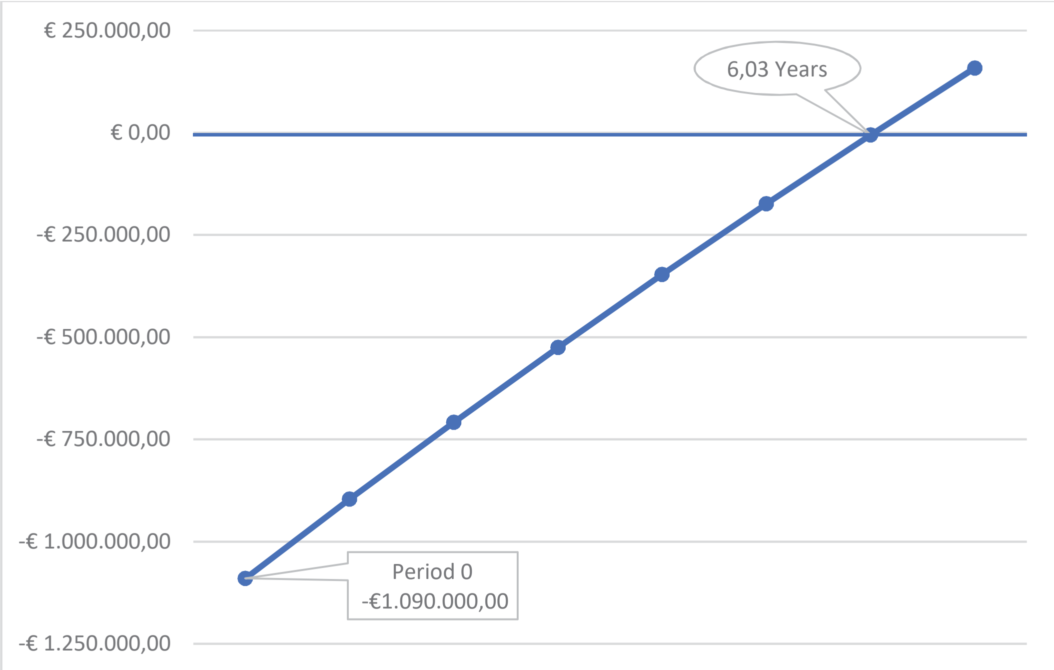
2.3.3 Scenario 2: the DPP best-case

Scenario 2 is characterized by a discount rate equal to 2,84% and the same assumptions made for scenario 1 and discussed in section 2.4.2. Whereas, the selection process of discount rate is explained in section 2.4.1: it is the 2018 annual average yield of 15 years Italian treasury bills.

Regarding the best-case, illustrated in chart 4, a lower discount rate anticipates the discounted payback period by 6 months: it becomes substantially six years. The effect of the change is positive because the company gets back its money after six years, four years before the accounting depreciation and six years before the ending of machines life cycle. This result is better than scenario 1 but, the discount rate used considers low opportunity-cost and low risks. The investment profitability might turn out as low in comparison with the eurozone because, an increase of interest rates within ten years can be expected. Furthermore, with such a technological progress an innovation can suddenly appear in the market, shake up the logistic sector and make the system obsolete earlier than expected.

Under current conditions the system is fairly acceptable and profitable as showed by results, especially if we take a look at the previsions for the following two years about real economy and interest rates provided by the European Central Bank: interest rates of both short-term and long-term government bond will decline within 3 years (European Central Bank, 2019).

Chart 4 - Discounted Payback Period: the best-case scenario 2

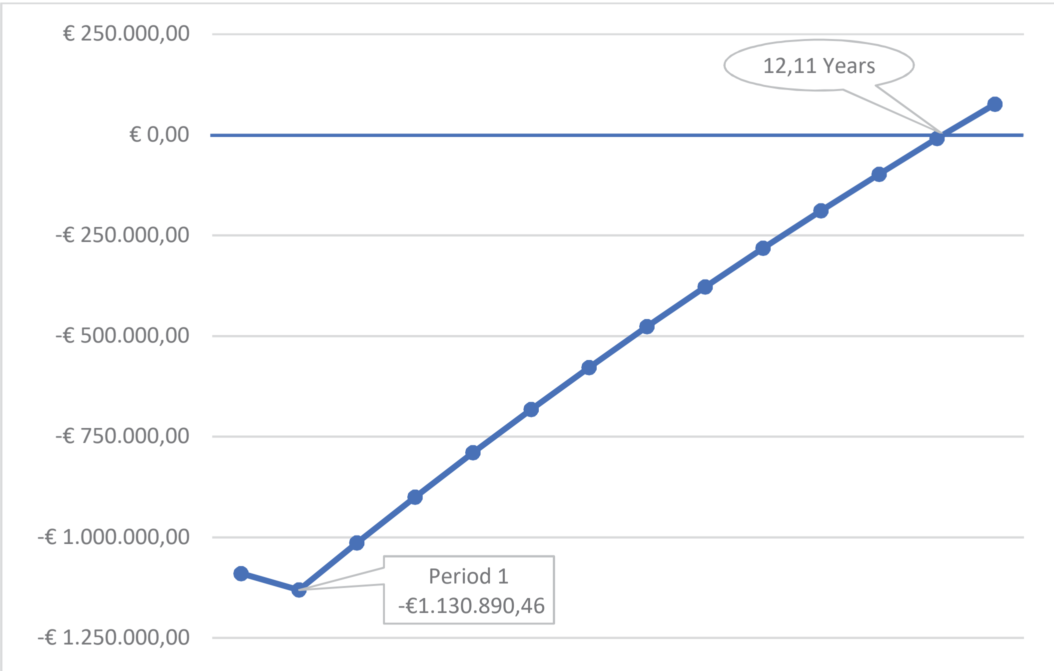


2.3.4 Scenario 2: the DPP worst-case

Also the worst-case has a significant improvement regarding the discounted payback period that from 14,62 moves to 12,11 years, as can be seen from chart 5. Here the effect is greater than the best-case, because the recovery is slower and the exponential effect of the discount rate repeats for more years. Even if the recovery is faster than scenario 1, the outcome is still negative because incremental cash flows are not sufficiently high to let the company regain the investment in time. The main obstacle is the first year characterized by negative incremental cash flow, that shifts everything of about two years. The break-even point is at the end of machines' life cycle therefore the company should not accept this outcome, but the latter one can turn into acceptable if environmental factors are the main reason for the investment. It is like Würth invests in fixed assets only for reducing its environmental impacts, with the risk of losing money because machines can stop working even before the time forecasted (12 years).

The company should focus its attention to replace the cardboard supplier as soon as possible in order to guarantee an important saving related to the cardboard costs.

Chart 5 - Discounted Payback Period: the worst-case scenario 2



2.4 NET PRESENT VALUE

For investments, where the expected cash inflows and cash outflows arise over time, Net Present Value is the standard approach of evaluation and it should be superior to other investments evaluation criteria such as payback period, internal rate of return, accounting rate of return, profitability index and others. Discounted cash flows analysis and NPV take into account the time value of money and riskiness of the investments, as represented by the discount rate with the opportunity cost of capital. So, the discount rate does not consider the entire risk of the project but only the systematic risks mentioned before (Accountants, 2007).

Using the NPV method, the present value of the investment outlay is compared to the present value of the project outflows and the difference between them is called the Net Present Value. If the difference is positive the investment is acceptable, otherwise it should be rejected. The method made also two simplifying assumptions: all cash flows, regardless the initial investment, occur at the end of periods and are immediately reinvested at a rate of return equal to the discount rate (Brewer, Garrison, & Noreen, 2010).

2.4.1 DISCOUNT RATE SELECTION

The discount rate adjusts future cash flows back to their present value, and it basically set the minimum acceptable rate of return for the investment analyzed. It is useful in judging whether the investments returns are at least equal to the costs of debt and equity funds (or the cost of capital) used by the business to acquire the asset. In the long run, the funds a company used to obtain the asset will come from both debt and equity. Therefore, the company should base the cost of capital calculation on the combination of debt and equity in the long run, not by considering the specific combination used to finance that investment (Ehmke & Boehlje, 2007). In this case, discovering the cost of capital of Würth Italy SRL is rather difficult because it is not a listed public company and the balance sheet is not publicly available. Furthermore, its financial statement is affected and included in the Würth Group reports and this might lead to an inconsistent analysis. In Würth Group financial statement are included activities extraneous to the core competences of the company.

I decided to choose the "Return On Assets" as a discount rate for scenario 1 because of simplicity and consistency. The ROA is the ratio between "Net Income", at the numerator, and "Total Assets", at the denominator. It is an indicator of the company profitability relatively to its assets and it considers also the company debts, differently to other rates such as ROE and ROS. The ROA allows evaluating the investment taking into account the equipment profitability and riskiness related to operating activities and it set the minimum rate of return for the new equipment. To stabilize the ratio, I have computed the average of 5 years as showed in table 4 (Cucculelli, 2019).

Table 4 – Return on Assets computations

Year	Net Income (in millions of €)	Total Assets (in millions of €)	ROA (in %)
2014	378	8.142	4,64
2015	434	9.210	4,71
2016	462	9.711	4,76
2017	531	10.267	5,17
2018	687	10.974	6,26
Average	498,4	9660,8	**5,16**

Source: elaborated of annual report of the Würth Group

To conduct a sensitivity analysis of results with respect to the discount rate, I run the analysis with another rate. To discount future cash flows in scenario 2, I picked an interest rate equal to 2,84%, the 2018 annual average yield of 15 years Italian treasury bills (Finanze, 2019). I selected the interest rate of 15 years treasury bills because the supposed machines life cycle time is within this period (12 years).

In my opinion, considering these factors is the minimun requirement a company must take into consideration while evaluating an investment made in a specific territory. Since Würth Italy SRL is a subsidiary operating exclusively in italy, the risk linked to its business is at least equal to the risk of governmental default. This nominal interest rate includes a risk premium for the possibility of default of the italian government and the expected inflation. The rate is relatively high because in 2018 markets were afraid about the political instability of the country, the so-called Italexit, the recession and the global unsteady situation. Therefore, risk mirrored by the interest rate is comparable to the risk attributable to a private investment of the same duration.

2.4.2 AN ANALYSIS BY FACTORS

As mentioned in paragraph 2.2, only incremental cash flows must be considered and the categorization made (sunk costs, opportunity costs and side effects) helps to identify them. Most projects have typical kinds of cash outflows: the initial investment (including the equipment, installation costs and other assets), increasing working capital needs (for example, opening a new shop require a company to allocate liquidity in form of cash and/or inventory for running it), ordinary repairs and maintenance and incremental operating costs. They also have typical cash inflows: incremental revenues or reductions in costs, salvage value at the end of the period and the release of working capital (Brewer, Garrison, & Noreen, 2010).

2.4.2.1 Capital spending

The initial capital outlay will be the same for both scenarios (best and worst cases) because the company has already negotiated the prices with suppliers. It includes:

- N° 2 tray erector machines and relative parts
- N° 2 lidding machines and relative parts
- Packing and delivery

- Installation, commissioning, training and 5 days special assistance
- Automated glue feeder
- Spare parts kit
- 12 months additional warranty
- Adaptation of the palletizer robot (software and relative parts)

All the components are essential to run the new system and therefore must be counted in the expenditure. The total amount is equal to €1.090.000,00.

2.4.2.2 Filling materials

There are four different types of materials used to fill the unoccupied spaces that I nicknamed as follow: “Plastico1” (plastic bubble wrap), “Plastico2” (plastic air pillows), “Papero1” (crinkled paper tubes) and “Papero2” (crinkled papers). Table 5 shows costs related to the materials consumption in the two filling stations created to substitute Alfa old shrink tunnels. The two stations are currently working to guarantee products safety.

Table 5 – Intermediate solution: filling materials consumption in 2018

	Consumption (in units)	**Price per unit**	**Expenditure**
Plastico1	36	€ 135,00	€ 4.860,00
Plastico2	576	€ 84,00	€ 48.384,00
Papero1	640	€ 33,44*	€ 21.403,20
Papero2	72	€ 37,80	€ 2.721,60
		TOTAL	**€ 77.368,80**

*it is the weighted average between the costs per unit of two different purchasing orders in the same year

Source: purchasing orders (provided by Vincenzo Montilli)

To forecast the saving about filling materials I based my previsions on a statistic about the case calculation outputs, run in May 2019. This statistic was made by Daniele Baldassarri analyzing the free volume in each carton. The simulation of one month has been made for two formats with identical input files[3]: the current cartons set (high 475x240x275; low 475x115x275; small 330x125x90) and the future cartons set (big 478x293x286; small 378x213x286; extra small

[3] Dimensions are declared in millimeters, in the following sequence: "length" x "height" x "width". Those are internal dimensions for calculating the precise volume usable.

280x100x150), both with the classic strategy. There are two strategies of virtually placing products in the box: the classic and the new strategy. The classic strategy consists of simply optimizing the volume. Instead, whenever possible the new strategy consolidates the same positions into a single carton, other than simply optimizing the volume. The system is running with the classic strategy because there was an attempt to implement the new strategy, but the algorithm crashes every time it meets packing rules. To optimize volume, the algorithm places articles into cartons according to their characteristics (size, weight, package size, standing-up flag which means the article must be always put up in the box, flexible flag that means the article can be squeezed and only the volume becomes relevant and stacking flag), the defined quantity that must be packed and the container properties (size, maximum weight and filling degree). The simulation provides as output a list of packages with its contents (Baldassarri, 2018).

I have analyzed the free volume of current cartons set in the simulation and I have also predicted the free volume after the folding of future cartons set, basing the prediction on a linear relationship between *free volume* and *filling material consumption*. I have computed the following proportion: if for a volume equal to "X" an amount "Y" of filling materials is used, for a volume equal to "Z" an amount "W" of filling materials is used.

In the worst-case I have considered that are folded about 49% of cartons, where most of the volume is saved. The percentage derived from an analysis on measurements made directly in the field, with the current carton set. I have extrapolated the number of **high** boxes folded over the total of high boxes, because their dimensions are more similar to the new format that will be used with new machines (the higher cartons we have, the wider will be the folding range). Applying the 49% to the future carton set outputs of the case calculation leads to a free volume reduction of 38,59%, respect to the free volume of the current carton set, because the total volume is wider due to bigger boxes.

Instead, for best-case the total elimination of filling materials is considered. It is possible thanks to the algorithm optimization (the procedure by which products are placed as optimally as possible inside boxes, according to dimensions, weight, space and so on), that can combine optimally products' placement with the new machine feature and operators' ability to manage possible empty spaces. Results of the analysis are showed in table 6[4].

[4] The results come out of the analysis briefly explained above. To check the analysis, there is a spreadsheet that can be viewed by requesting it directly to the author.

Table 6 – Filling materials cash flows

	Monthly expenditure	Costs saving	Annual expenditure	Incremental cash flows
Intermediate solution 2018	€ 6.447,40	0%	€ 77.368,80	***€ 0,00***
Worst-case	€ 3.959,06	38,59%	€ 47.508,75	***€ 29.860,05***
Best-case	€ 0,00	100%	€ 0,00	***€ 77.368,80***

2.4.2.3 Returns

In 2018, the total amount of returns counted for over 16 million of euro. They are divided into 6 categories (commercial, administrative, courier, logistic, product quality and other) that are split again into 20 subcategories, each one representing a specific cause. I have analyzed only the articles included in the subcategory of logistic: "article/delivery damaged", that in 2018 counted for over 500 thousand of euro. I chose this subcategory because there are included the problem caused by the bad quality of packaging and void inside them, which might entail in damaging the contents of cartons during the delivery.

Thanks to the support of Vincenzo Cerrone, through SAP IW1 we have been able to extract the articles processed in Capena, by the automated packaging line in warehouse "A", from the total returns ascribable to the subcategory "article/delivery damaged" (that includes also articles processed in the headquarter based in Egna, the warehouse “X” and manual packing in Capena). From that analysis, a list of articles with corresponding quantities and turnovers came out. The list, as said before, is directly linked to the articles processed by machines object of the thesis. Supposing an improvement on the packaging robustness, that should guarantee safety to the contents, with new machines there is a potential saving:

- In the best-case, equal to 49% of the value of the articles processed in warehouse “A” by the automatic packaging line. The 49% corresponds to the number of *high* cartons hypothetically folded at the precise height, according to the observations with the current carton set (*high* cartons because those are more similar to the future carton set, so the folding range is even wider than that and more cartons are supposed to be folded precisely).
- In the worst-case, equal to 55% of the previous value considered in the best-case. This percentage derives from the analysis of damaging reasons. Basically there are 4 reasons: too void in the package (0,55), operators damage the content during the box preparation (0,10), couriers that mistreat packages (0,30) and other (0,05). I have attributed the weight to each reason according to the experience accumulated through participating in each process.

Table 7 – Returns cash flows

	Impact on the packaging sturdiness	Incremental cash flows
Best-case	49%	€ 14.028,72
Worst-case	27%	€ 7.715,80

2.4.2.4 Cardboard

Now, I am going to call "ImballingOne" the only manufacturer able to observe the quality standards requested by Würth for the current carton set.

There is the holding company of the group that has its headquarters located in Switzerland. The group is present in 16 countries all over Europe, but not in Italy. Therefore, the logistic center of Würth located in Capena needs to restock directly from Switzerland.

What are the standards guaranteed by the ImballingOne company? Sturdiness and solidity, high quality of customized printing, zero waste in every supply since years, precision and continuity of shipment. Furthermore, ImballingOne keeps in stock an amount of cardboards equal to one month of supply to Würth in order to assure more certainty. But such a long distance implies some disadvantages: substantial costs of transport (determined by fuel, highways toll, customs tax, personnel), minimum quantity of reorder (ImballingOne wants to fill at least one lorry to reduce costs) and risks.

To determine costs of cardboard supply and to ensure comparability, I used the quantities of cartons indicated in the case calculation for every situation: for the intermediate solution of 2018 and for the future carton set with new machines.

Table 8 – Intermediate solution 2018: cardboards consumption

	Price (per unit)	Annual quantity (units)	Subtotal	Total
High	€ 0,522	1.001.472	€ 522.768,38	
Low	€ 0,391	447.432	€ 174.945,91	**€ 697.714,30**

With new machines the cartons format and structure will change. The carton will be made up of a tray and a single lid (instead of a cardboard belt and two lids, one on the bottom and another on the top). There are much more manufacturers able to produce such a format of carton, so there is a wider choice. Moreover, some are located closer to Würth in Capena: it means cheaper costs of transportation and less risks related to it.

Until now, five different manufacturers' quotes and products quality have been examined, including the current supplier ImballingOne. A cardboard sample of each product was sent to Beta for performance test, and none of them passed probably because samples are made by a plotter with lower quality standards compared to mass-production equipment.

ImballingOne cartons are most close to the standards requested by the machines manufacturer because they have the best quality ranking among all. So, the strategy Würth will adopt to handle this issue is the following: starting with ImballingOne cartons that are most suitable according to the quality ranking and once the production will be settled, other cartons will be tested.

Currently, the low carton has a lower quality respect to the high, because it should hold up lighter weights. The initial test will be run with equal quality for both cartons, but a reduction for the smaller carton is considered in the best-case. That reduction will decrease the price of the smaller tray up to 10%, as the additional price proposal of the ImballingOne company suggests (Harders , Updates about the test at "Beta", 2019). Among the five alternatives, I have decided to choose ImballingTwo which provides an acceptable quality of cartons with a low price. The ImballingTwo society has a production site located in Anzio (Rome) that is really close to Capena, especially if compared to the distance from the ImballingOne site in Switzerland. This option eliminates problems related to distance and transportation costs, but other important variables need to be verified: timeliness and accuracy of the service, quality and reliability of the cardboard.

To conclude the cardboard future cash flows analysis (reported in table 9), I selected the ImballingTwo company as a supplier for the best-case, applying the 10%

reduction to the small carton price in light of the concrete possibility of lowering its quality. In the worst-case, ImballingOne company is set as the supplier during the first year and ImballingTwo for the following.

Table 9 – Cardboard cash flows

	Price (per unit)	Annual quantity (units)	Subtotals	Total expense	Incremental cash flows
Big	€ 0,550	666.216	€ 366.418,80	€ 593.965,40	**BEST-CASE**
Small	€ 0,349	651.996	€ 227.546,60		***€ 103.748,89***
Big	€ 0,710	666.216	€ 473.013,36	€ 776.517,50	**WORST-CASE 1**
Small	€ 0,466	651.996	€ 303.504,14		***-€ 78.803,20***
Big	€ 0,550	666.216	€ 366.418,80	€ 610.917,30	**WORST-CASE 2**
Small	€ 0,375	651.996	€ 244.498,50		***€ 86.797,00***

2.4.2.5 Electricity

The new system will lead to electricity saving because new machines has a lower power than the current ones. The total amount of power (expressed in kWh) is 42 for Alfa and 39 for Beta machinery. The economic saving is paltry because Würth electricity costs are significantly low (€0,055 kWh) (Harders, Budget new packaging line IT-W Capena, 2018). To compute the incremental cash flows I have considered on average 240 of working days per year and 11 working hours per day. Here, no distinctions between the best and worst-case are made.

Table 10 – Electricity cash flows

	Power (kw/h)	WH/day	WD/year	Kw/year
Case erector	16	11	240	€ 2.323,20
Case erector	16	11	240	€ 2.323,20
Lidding machine	5	11	240	€ 726,00
Lidding machine	5	11	240	€ 726,00
Total	*42*			*€ 6.098,40*
Tray erector (400x300)	7	11	240	€ 1.016,40
Tray erector (500x300)	10	11	240	€ 1.452,00
Lidding machine (400x300)	11	11	240	€ 1.597,20
Lidding (500x300)	11	11	240	€ 1.597,20
Total	*39*			*€ 5.662,80*
			Incremental cash flows	**€ 435,60**

Source: elaborated of technical files with the support of Fabio Forti

2.4.2.6 Glue

To determine the glue cash flows (indicated in table 11) I have considered the following information:

- In the old system both cartons have the same area of application. A line on the bottom and another one on the top to fastening the two lids to the cardboard belt, for a total of 320 cm per box (Forti, 2019). I calculated the total area of application considering the number of boxes reported in the case calculation: 120.742 boxes in total;

- With the new system the application is different, so I based the measuring on illustrations reported in the technical files. The big carton will have 324 cm and the small one will have 224 cm of glue application (the total times 55.518 big and 54.333 small boxes);
- In the best-case I have considered also a 20% of further saving according to what declared by suppliers. They affirm this type of glue has higher performance thanks to lower specific weight and better efficiency. Here, I picked the lowest price proposed by suppliers, even if the glue is not already tested;
- In the worst-case I have considered half of what suppliers declared (so a 10% further saving). Here, I picked the highest price of a glue that is already tested.

Table 11 – Glue cash flows

	Consumption (in kg)	**Saving (in %)**	**Price (per kg)**	**Annual expense**	**Incremental cash flows**
Ethylene-vinyl acetate glue	6000		€ 2,45	€ 14.700,00	
Metallocene glue					
• Worst-case	4200	30%	€ 3,80	€ 15.960,00	***-€ 1.260,00***
• Best-case	3600	40%	€ 3,10	€ 11.160,00	***€ 3.540,00***

2.4.3 OUTCOMES DISCUSSION

In this section I am going to explain what the results of the economic assessment are. I have developed two scenarios, with a best-case and a worst-case each. They differ only regarding the discount rate, whereas the other components remain unchanged: incremental cash flows and periods analyzed. The reason I built two scenarios is for observing the sensitivity of the analysis with respect to the discount rate, and the influence it has into the assessment. I extended the analysis until twelve periods, equal to the time the old machines have been working minus one year, considering a more aggressive technological progress.

It is important to highlight that the following factors felt outside of the analysis:

- Environmental impacts that will be integrated into the assessment in chapter 4.

- Return in terms of image determined by higher quality of packaging and reduction of filling materials. So, thanks to a more qualitative service in general. These factors are highly important for the management of the company because the customer-oriented strategy is the basis of the Würth business. They are excluded because the estimate of the service qualitative improvement is undefined, especially if compared to the customer feelings. Monetizing such ambiguous parameters might lead to erroneous assessment. But the management can easily affirm that the impact will be positive even because it is proved by the implementation of the same system in foreign branches of the company.
- Further negotiations with couriers and suppliers. Currently, some of them are at the early stage and there is further margin to reduce costs. For example, the management is waiting for additional proposals regarding the cardboards and glue supplies. In addition, there is a concrete possibility to renegotiate the contract with couriers since there will be a reduction of the shipments volume. Quantifying the effect of these factors is almost impossible because I have not any historical reference point and they depend on capacity to contract of parts, human factor, uncertain outputs and market conditions.
- Risks and costs related to have a single supplier of cardboard far away from the Würth logistic center. Even if risks are weakened by agreements within the two companies (ImballingOne holds in its warehouse an amount of stock equal to

about one month of supply and Würth keeps in stock about 4 times the quantity re-stocked each period that is rather constant), these agreements weigh on Würth: the quantity stocked by ImballingOne is charged indirectly on the price to Würth and the stock kept by Würth involves its money and space.

2.4.3.1 Scenario 1: the NPV best-case

This case takes into consideration the most positive consequences of the system (showed in table 12). I want to say also here some factors, that should have a positive impact on the investment, felt outside the analysis for the reasons explained at the beginning of this section.

Table 12 – The best-case incremental cash flows

Source	Incremental cash flow
Filling materials	€ 77.368,80
Returns	€ 14.028,72
Cardboard	€ 103.748,89
Electricity	€ 435,60
Glue	€ 3.540,00
TOTAL	**€ 199.122,01**

The factor which affects mostly the analysis, as in the worst-case, is the costs of cardboard. I considered a supplier with cheaper price and lower quality than the ImballingOne company, and an additional reduction of 10% to the price of small carton (due to the possibility of reducing the quality of that type), as clarified in section 2.4.2.4. Anyway, it is not the cardboard with the worst quality and cheapest price, but it is a balanced option. Compared to the cardboard supply of old system, the alternative saves one hundred thousand of euro each year and it determines the most important economic impact. However, only after trying cardboard the Würth will know if the quality of other suppliers is acceptable or not.

Following for importance, the filling materials consumption has a bearing of almost 78 thousand euro. I hypothesized the best alignment of the algorithm with machine restrictions, with the ability of operators to place products effectively as well as efficiently. So, the consumption has the potential to become null after a training period, where the IT department and field operators become confident with the new system.

Also returns have an impact on the turnover and creating a perfect packaging throughout a flawless process can imply a considerable saving. For example, in 2018 almost 30 thousand of euro were lost due to articles and/or delivery damaged. Even if the problem cannot be eliminated totally because the causes of damaging come also from sources out of the company control, the phenomenon can be attenuated through the folding machine.

Regarding electricity and glue, their only economic impact is negligible because differences between the solutions are little and related costs are not substantial: the electricity rate paid by Würth is risible and the glue consumption is low.

Chart 6 – Cumulative Net Present Value: the best-case scenario 1

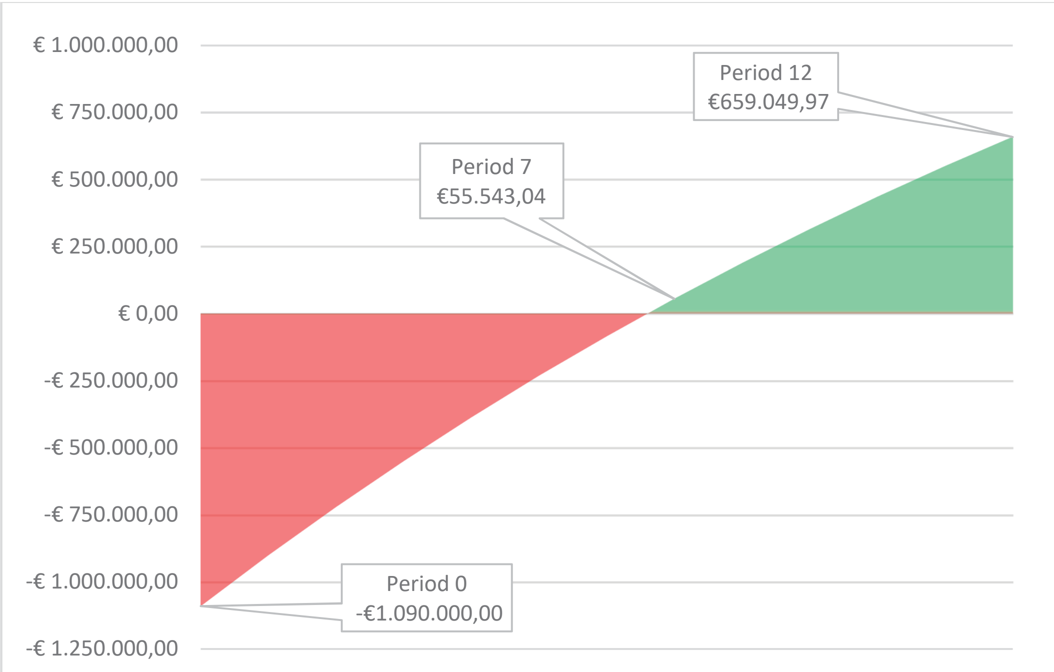


Chart 6 shows results of the best-case cash flows, highlighting major points. Period zero is unchanged because the capital spending is the same in both cases.

The cumulative NPV remains negative until period seventh, when it turns positive for a total of more than 50 thousand of euros so, it means Würth starts to benefit from it after seven years. It is a good result given the type of investment, especially without considering the environmental benefits that it will bring to the supply chain. As already mentioned during the discussion about DPP results, the depreciation ascribed in financial statements will be 10 years and 13 years is the life cycle of machines in dismantling. Considering a more aggressive technological progress *Beta* machines will become obsolete sooner than the *Alfa* system therefore, the machine's supposed life cycle would be 12 years. This analysis does not consider other factors explained above, so the impact could be better than what showed by this NPV outcomes.

At the end of the supposed machines life cycle (12 years) the cumulative NPV amounts to more than 650 thousand of euros, that is about 59% earnings of the initial outlay.

2.4.3.2 Scenario 1: the NPV worst-case

In the evaluation, considering the worst for each factor lead to a negative result. Additionally to the skip of factors mentioned just above, in the worst-case all the negative consequences are included, as can be seen in table 13.

There is a distinction between the incremental cash flows of the first and following years that is determined by the cardboard component. In the first year, the highest quality and most expensive cardboard supply from ImballingOne company is included: considering possible problems raised by Beta about the cardboard quality, that rejected all samples sent for quality test (reasons explained in section 2.4.2.4), the management want be sure to avoid problems during the implementation of the system and it will start the production with the most qualitative cardboard. For the second year onwards, the incremental cash flows change because the ImballingTwo supply replaces the ImballingOne's cardboard: once the system got up to speed and the implementation phase is over (together with adjustments to the whole process), management wants to introduce other cartons from different suppliers. So, I decided to pick another company, that I am going to call "ImballingTwo" as valid alternative because it discloses best characteristics in terms of quality and price.

Table 13 – The worst-case incremental cash flows

Source	**Incremental cash flow 1st year**	**Incremental cash flow 2nd year onwards**
Filling materials	€ 29.860,05	€ 29.860,05
Returns	€ 7.715,80	€ 7.715,80
Cardboard	-€ 78.803,20	€ 86.797,00
Electricity	€ 435,60	€ 435,60
Glue	-€ 1.260,00	-€ 1.260,00
TOTAL	**-€ 42.051,75**	**€ 123.548,44**

Here, what affects mostly cash flows is the cardboard supply that has an extremely high impact. At the beginning, even if the cardboard production in number will be lower than the old system, the price of the high-quality cardboards affects negatively the incremental cash flows. Differently, after the first year and the introduction of ImballingTwo provision, incremental cash flows turn into positive although the bad conditions applied to the other components.

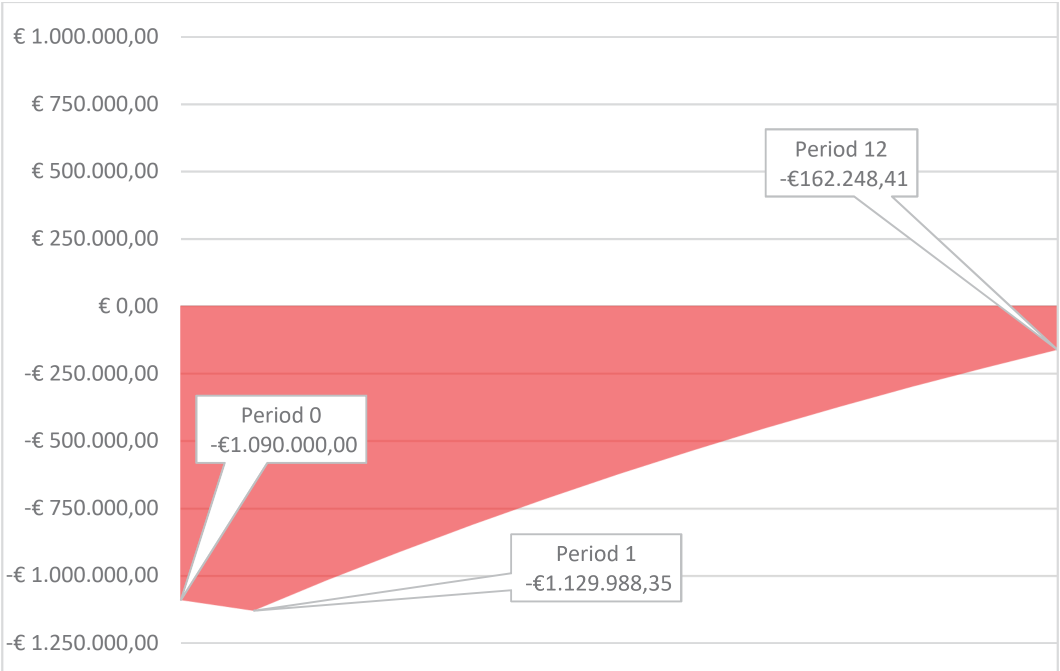
Even in the worst case, the new machinery will lead to a reduction of filling materials which will guarantee significant annual savings in terms of money. This saving amount to almost 30 thousand of euro, which is the second most important impact. It is the factor that guarantees a decent annual savings without any risk, even if on its own it cannot justify the entire investment that is 36 times as much.

The glue consumption has a negative but reasonable influence on the total. In despite of 30% saving (thanks to properties of the new glue type and to a smaller area of application) the high price determines an increase in costs. That price comes from a supplier proposal for a glue certainly suitable to the new machines but, it can be negotiated further and other types of glue at lower prices will be tested.

Returns have a moderate but positive effect thanks to the machinery's ability to make packages more robust. The estimate takes into account the effectiveness of machine’s ability to fold boxes and products inclination to be damaged.

Electricity has a positive but irrelevant impact considering its proportion (it is the 0,04% of the investment). Electricity costs are too paltry to determine significant economic savings but, its use reduction has beneficial advantageous environmental consequences.

Chart 7 – Cumulative Net Present Value: the worst-case scenario 1

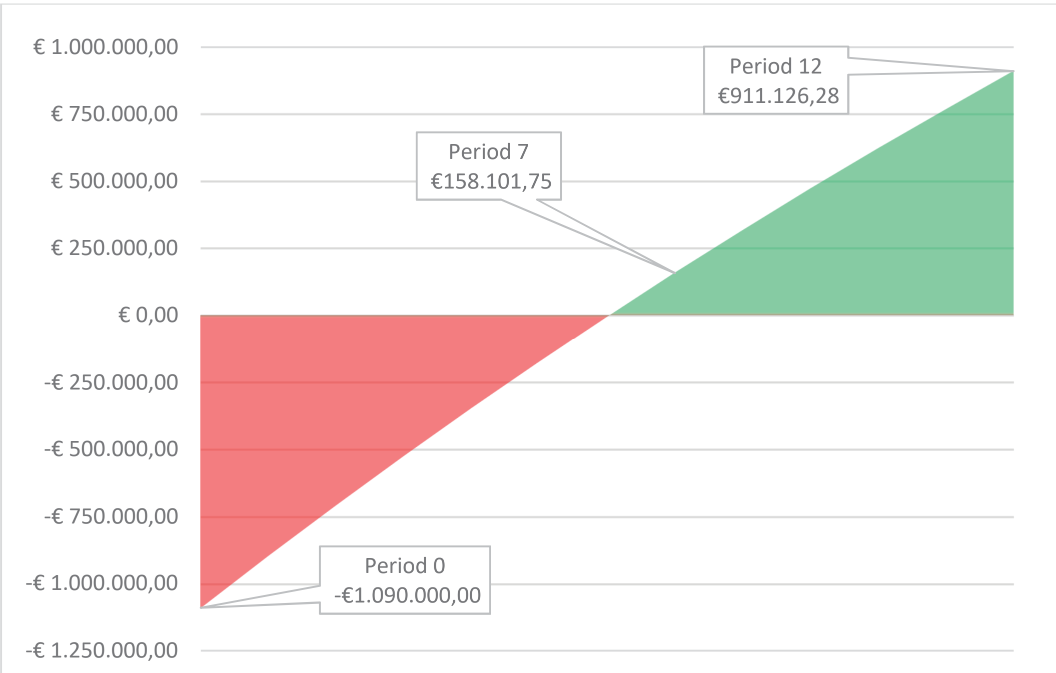


As can be seen from chart 7, starting from a disbursement of 1 million and 90 thousand euros and losing about 42 thousand euros the first year, the lowest peak is reached at the end of period 1. Due to the time value of money, the first year of losses is worth more than money saved during the following years so the NPV takes a very long time to become positive. Indeed, years of saving are discounted more than the first year of losses, therefore the recovery is weaker year after year. Only the fifteenth period, which is not depicted in the figure, has a positive value of about 21 thousand of euro. The result is clearly bad: the time of recovery is almost the double of the accounting depreciation time and much longer than the supposed life cycle of machines.

2.4.3.3 Scenario 2: the NPV best-case

As the worst-case of scenario 2, here the difference consists of only the discount rate. Chart 8 depicts the cumulative NPV highlighting the most relevant points.

Chart 8 - Cumulative Net Present Value: the best-case scenario 2

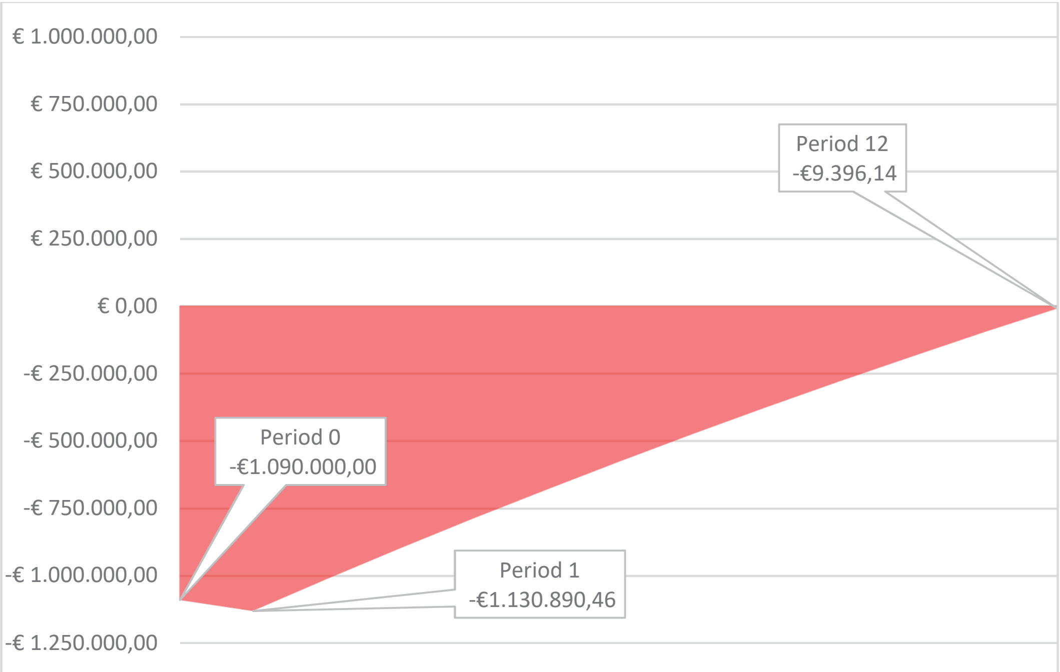


Also the best-case shows an improvement of results compared to scenario 1 because of motives explained just above: the discount rate has an exponential effect on NPV therefore, its decrease implies a hike of cumulative NPV. This enhancement is even greater than the worst-case of the same scenario, because it is not counterbalanced by negative cash flow of the first year. The cumulative NPV at the twelfth period is more than 910.000€, in comparison with scenario 1 it is almost 250.000€ higher. The first positive value appears at the beginning of the seventh year, anticipating the recovery of less than a year with respect to scenario 1. At the end of the supposed life cycle time, the investment produces earnings of about 83% of its value, without taking into account the non-monetary and unpredictable factors. It demonstrates the full potential of the investment to elicit great consequences.

2.4.3.4 Scenario 2: the NPV worst-case

As explained at the beginning of this section, scenario 2 differs only for the discount rate, whereas incremental cash flows and periods analyzed are identical to scenario 1. The discount rate considered here is equal to the average interest rate of 15 years Italian treasury bills issued in 2018. The reasons behind the choice are expressed in section 2.4.1.

Chart 9 - Cumulative Net Present Value: the worst-case scenario 2



What chart 9 shows is clearly a negative result. At the end of the supposed life cycle of machines, the cumulative NPV still reveals a loss but, comparing it to the result of the twelfth period of scenario 1 a significant improvement can be seen: changing the discount rate, from 5,16% of scenario 1 to 2,84% of scenario 2, leads to a gain of more than 150.000 euros in twelve years. This sum is greater than the incremental cash flow of one year, considered in this worst-case. The NPV is really sensible to a change of the discount rate because it has an exponential effect on the cumulative NPV therefore, comparing two scenarios, the difference between incremental cash flows is bigger every period.

Despite the improvement compared to scenario 1, the result of the worst-case is not acceptable because after twelve years the investment is not still recovered. Rather, there is still a loss under these conditions that should not be justified by the factors not involved in this analysis (listed at the beginning of the paragraph).

CHAPTER 3 - THE ENVIRONMENTAL ASSESSMENT

The chapter is dedicated to compare new system and intermediate solution in terms of environmental impacts. As for the economic assessment, I have not considered the old system due to lack of information and insignificance of the comparison. Therefore, the analysis is focused on comparing the investment in *Beta* machines to the intermediate solution, both described in chapter 1. The purpose of the environmental assessment is to determine a priori whether the investment has the potential to make the packaging process environmentally more efficient. The evaluation is made by comparing inputs of the economic assessment which have environmental relevance: cardboard, electricity, glue and filling materials (recycled paper and plastic).

I have not analyzed the following factors:

- Old machines disposal. It is impossible to figure out purposes of the several parts because machines are composed of many components such as aluminum, brass, PVC, steel, nylon, iron and so on. For example, old shrink tunnels were disassembled and some components became spare parts, others were adapted to different purposes or laid down somewhere (Stefani, Technical information about the machines, 2019).
- Maintenance works. Maintenance technicians of Würth have been handling operations with an ad hoc approach thanks to experience and their

competencies (Stefani, Technical information about the machines, 2019). Currently, there are not specific information about maintenance activities for new machines. Therefore, it is rather impossible to determine and to evaluate any difference between the two solutions and in any case, it should be not relevant.

- Returns. Also here, it is difficult to figure out the environmental impact of the new packaging system related to them: even if a reduction of returns can be supposed (thanks to the improvement of packaging quality) there is not any evidence to link the return prevented and its ending. Returns can have several destinations that imply different impacts on the environment: a product sent back due to damaged delivery can be repacked, sent to another subsidiary, thrown away and others according to its features and status. Therefore we cannot know if it becomes waste immediately, if it will be used after the repackaging or whatever. Anyway, using additional paper and plastic to repack items, delivering again to a customer or to a subsidiary, wasting items immediately or after their usage, are not regular processes. Furthermore, these processes have not substantial environmental impacts and they can be excluded from the analysis.
- Glue. This material is made of several components: polymers, resins, waxes, antioxidants and plasticizers. Different type and combinations of the mentioned components give to the glue diverse properties

(Hotmelt.com, 2019). It was impossible to discover the specific composition of both glues interested and the corresponding LCA that investigates the same products with similar characteristics. Therefore, I have not performed any further study on this factor in order to avoid providing inconsistent and too generic results.

3.1 METHODOLOGY

Due to constraints on competencies, resources and time it was not possible performing a Life Cycle Assessment for each factor. Therefore, I investigated the literature to find the most suitable existing LCA which I adopted to evaluate the following factors: filling materials (paper and plastic), cardboard and electricity. The evaluation is made through the "benefit transfer" practice. The benefit transfer is the use of existing studies to analyze and to evaluate other projects with all the related issues regarding changes in context, uncertainties and site-specific characteristics (Morrison, Bennett, Blamey, & Louviere, American Journal of Agricultural Economics). I referred to the Life Cycle Assessment studies because it is a structured method to assess impacts on the environment and human beings associated to goods and services. It analyzes the whole life cycle of the system considering the productive process from upstream to downstream activities (Guinée, et al., 2011).

The basis for comparison is set to one year, considering requirements instructed by historical data, case calculation of May 2019, technical files of machines and materials, previsions. The logic is identical to the economic assessment, considering the same assumptions and data.

3.2 FILLING MATERIALS

As mentioned above, operators use four different types of materials to fill the unoccupied spaces inside boxes: Plastico1 (plastic bubble wrap), Plastico2 (plastic air pillows), Papero1 (crinkled paper tubes) and Papero2 (crinkled papers). Würth has two suppliers, one for paper and another one for plastic products.

3.2.1 PAPER

In this section the environmental impacts related to the hypothetical saving of paper, used as filling material, will be estimated. Two products belong to this category: Papero1 and Papero2. The first one is a system that produces crinkled paper tubes with large volume. It is the most used of this category because takes up large spaces and weakens shocks: the usage is almost 9 times in terms of units and more than 15 times in terms of weight, in comparison with the Papero2 system. Instead, the second system produces a paper cushion with a peculiar shape suitable for small packages and therefore is less likely to be employed in the packaging line analyzed. These products are composed by recycled paper, as indicated by the recycling code (22 PAP). To predict environmental consequences caused by their usage reduction, the same assumption made in the economic assessment and discussed in section 2.4.2.2 are considered. Table 14 recalls the estimated consumption and saving of paper in terms of kilograms.

Table 14 – Paper consumption and saving (annual)

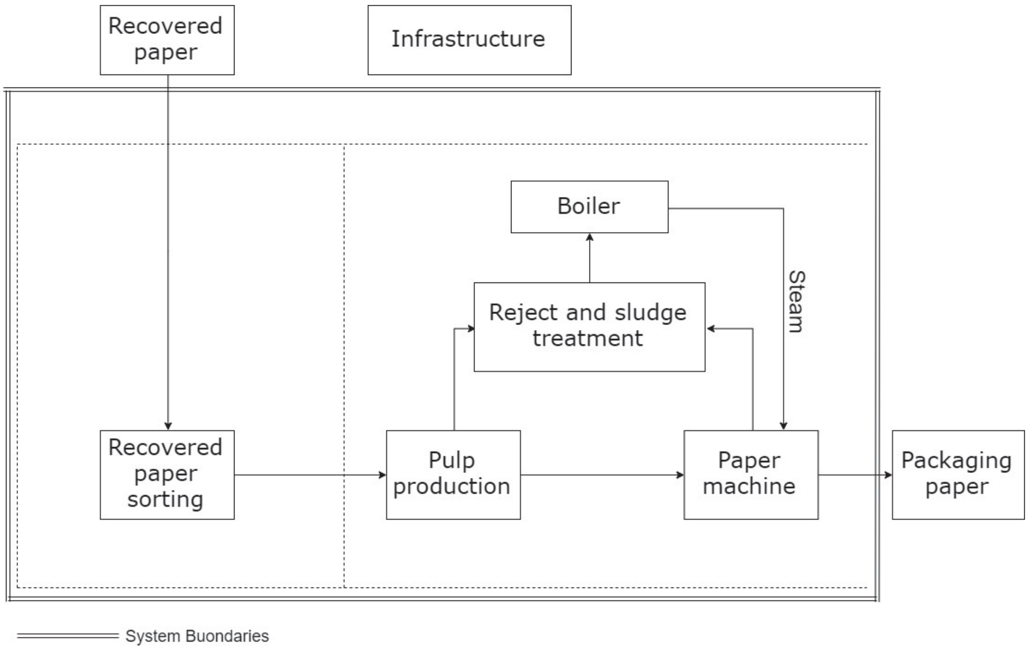
	Best-case	**Worst-case**
Free volume saving (%)	38,59%	12,94%
Paper consumption (kg)	6114	8668
Paper saving (kg)	**3842**	**1288**

The paper "Assessing environmental impact of packaging paper production based on recycled fiber raw material" is taken as a reference to understand the environmental impacts of paper production. It analyzes the recycled packaging paper manufacturing and includes the following stages within its system boundaries, as showed by figure 6 (Iosip, Dobón, Hortal, & Bobu, 2014):

- Recovered paper sorting operations, including use of electricity, internal transports, ancillary materials, materials as well as waste treatments and emissions;
- Recovered paper transport from the collection centers to the paper mill;

- Paper mill operations, including use of electricity, chemicals, internal transports, ancillary materials, packaging materials as well as waste treatments and emissions.

Figure 6 – Recovered paper LCA boundaries



Source: elaborated of Iosip, Dobón, Hortal, & Bobu, 2014

The case study is based on measurements and characteristics of a Romanian paper mill with a functional unit of 1 tone of packaging paper. Table 15 shows the results considering the quantities of recycled paper hypothetically saved with new packaging machines. Therefore, it indicates the avoided environmental impacts to produce 9956 kg of recycled paper in the best-case and 3842 kg in the worst-case.

Table 15 – Impact categories of paper

Indicator	Unit	Worst-case	Best-case
Abiotic depletion potential	Kg Sb - eq.	23,28	60,33
Acidification potential	Kg SO_2 - eq.	61,55	159,50
Eutrophication potential	Kg PO_4^{3-} - eq.	2,50	6,47
Climate change	Kg CO_2 – eq.	2658,28	6888,56
Photochemical ozone creation potential	Kg C_2H_4 - eq.	3,50	9,06
Human toxicity potential	Kg 1,4-DCB eq.	854,27	2213,72

Each activity of the production cycle contributes differently to impact categories. For example, production of chemicals is the major contributor in Eutrophication which is the category with the most significant impact in normalized results. Instead, the manufacturing unitary process includes operations such as recovered paper processing, paper machine functions, boiler and rejects/sludge treatment and these affect mainly categories such as Acidification and Photochemical Ozone Creation. The recovered paper processing, the paper production, the wastewater and reject treatments cause air emissions and therefore contribute mainly to Climate change and Human Toxicity. As can be expected, transportation is the major source if NO_2 caused by fuel consumption and influences mainly Eutrophication, Climate change and Photochemical Ozone Creation categories (Iosip, Dobón, Hortal, & Bobu, 2014).

The normalization step made by the study shows the relative impact of each category and the Eutrophication dominates the other, as said before. It includes all the potential impacts caused by high levels of macronutrients (nitrogen and phosphorus are the most important) in the environment. Those can cause elevated biomass production in aquatic and terrestrial ecosystems and they might also render surface water unacceptable to drink (Guinée, Handbook on Life Cycle Assessment, 2002). Furthermore, Eutrophication is followed by AP and Climate Change categories that are relevant whereas ADP, HTP and POCP have a reasonable effect (Iosip, Dobón, Hortal, & Bobu, 2014). Regarding the Acidification Potential, the common acidifying pollutants are SO_2, NO_x and NH_x that can affect areas such as the natural environment and resources, the man-made environment and the human health. The increasing fish mortality in lakes, the crumbling of building materials and forest decline are example of potential general consequences of pollutants spread. Whereas, the Climate Change consist of all greenhouse gases converted into CO_2 emissions through the corresponding index of Global Warming Potential (GWP) and it has an international relevance. Greenhouse gases emissions impact the radiative forcing of the atmosphere and they potentially damage ecosystem health, human health and material welfare (Guinée, Handbook on Life Cycle Assessment, 2002).

It is important to mention that the study taken as a reference is focused on packaging paper production in Romania and it might not be perfectly applicable to our case. Some parameters are directly linked to the geographical area, techniques, technologies adopted and therefore they can easily differ from a country to another, from a production site to another: for example, the electricity production data are based on national mixes.

3.2.2 PLASTIC

Plastico1 and Plastico2 are the plastic products used as filling materials and therefore belong to this category. The first one is bubble wrap and the second one is air pillow, made of plastic. Bubble wrap are used mostly for protection because sturdy and heavy. For example, they protect boxes against pointy and heavy objects or fragile products against blows. Instead, air pillows are necessary to fill the empty space and to avoid movements of content, because are voluminous but breakable. Plastico2 is used 16 times Plastico1 in terms of units and almost 10 times in terms of weight.

Plastico2 product is composed of HDPE (High Density Polyethylene), as indicated by the recycling code (02 HDPE) printed directly on the product and packaging. Regarding Plastico1, the recycling code defines the material as "all other plastics" therefore, to perform the environmental analysis I assumed both products to be made of HDPE. The consumption is generously higher for the Plastico2 so, the impact of Plastico1 is lower and the assumption made should not drive results too far from the reality. Probably, the impact of the latter is underestimated by assuming it equal to HDPE.

To assess the environmental benefit from a reducing consumption of these plastic products, I have considered the logic adopted for the economic assessment: a linear relationship between material consumption and free volume with the relative calculations explained in section 2.4.2.2, split into best and worst case. Results about the plastic consumption and savings in terms of kilogram are showed in table 16.

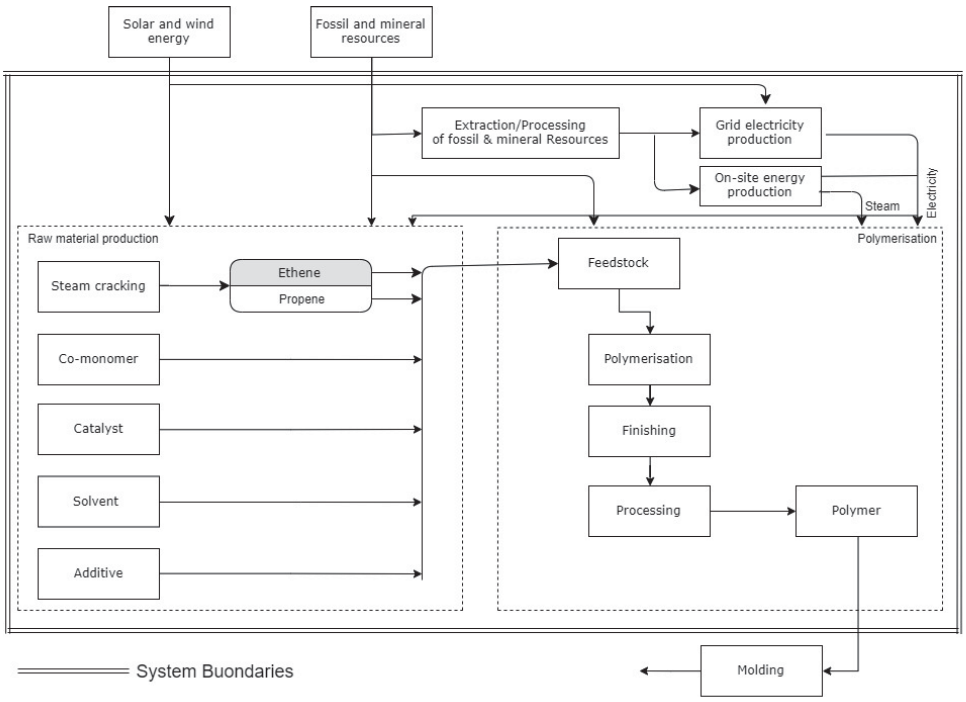
Table 16 – Plastic consumption and saving (annual)

	Worst-case	**Best-case**
Free volume saving (%)	38,59%	100%
Plastic consumption (Kg)	3.557	0
Plastic saving (Kg)	**2.236**	**5.793**

To generically quantify environmental impacts caused by polyolefins production, I used the Eco-profile and Environmental Product Declaration performed by PlasticsEurope AISBL of European Plastics Manufacturers. The analysis was performed by collecting data from the most important European producers to generate an industry average. Therefore, it is not specifically linked to the plant where the polyolefins are taken to produce Plastico2 and Plastico1 products. The impact depends on technology, raw materials and energy used during processes, but it should give approximate but reliable values to base an environmental assessment. The paper treats the production cradle to gate of High-density Polyethylene (HDPE), Low-density Polyethylene (LDPE), and Linear Low-density Polyethylene (LLDPE) resins. As reported in the document, within the cradle-to-gate Life Cycle Inventory system boundaries are included the following processes, depicted also in figure 7 (PlasticsEurope AISBL, 2014):

- Extraction of non-renewable resources (e.g. of oil and natural gas);
- Growing and harvesting of renewable resources (e.g. biomass production);
- Beneficiation or refining, transfer and storage of extracted or harvested resources into feedstock for production;
- Recycling of waste or secondary materials for use in production;
- Converting of non-renewable or renewable resources or waste into energy;
- Production processes;
- All relevant transportation processes (transport of materials, fuels and intermediate products at all stages);
- Management of production waste streams and related emissions generated by processes within the system boundaries.

Figure 7 – HDPE LCA boundaries

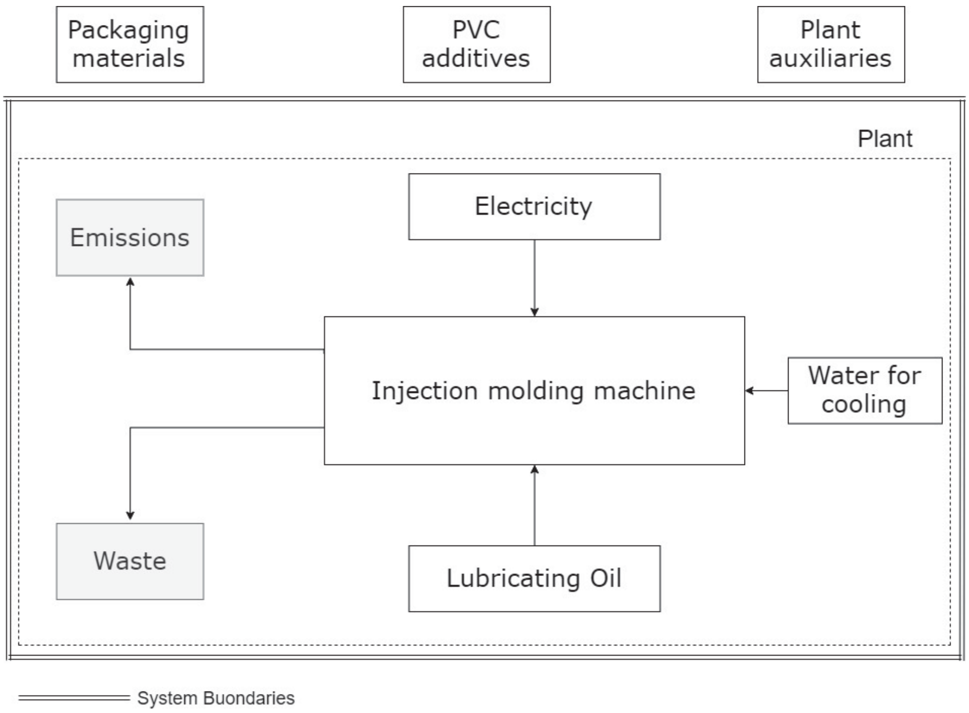


Source: elaborated of PlasticsEurope AISBL, 2014

The molding process remains outside the system boundaries of the EPD provided by PlasticsEurope. It transforms the HDPE resin into a mold, the finished good ready to be packed and shipped. Therefore, to conclude the impacts evaluation of plastic, “Environmental impact analysis of the injection molding process: analysis of the processing of high-density polyethylene parts” and its results are integrated into the impact assessment. The paper analyzes the environmental impact of the injection molding of HDPE, removing values not directly related to this raw material from the injection molding dataset of EcoInvent v3.01. Here, the functional unit is 1 kilogram of injected plastic. Considering a waste of 0,005 kg of plastic per functional unit and the volume object of the analysis, results are comparable to the LCA of HDPE production (where the functional unit is 1 kg of HDPE resin). The system boundaries of this analysis include the following components (see figure 8) (Elduque, Elduque, Javierre, Fernandez , & Santolaria, 2015):

- Lubricating oil
- Electricity consumption
- Water for cooling
- Plastic waste
- Emissions
- Infrastructure
- Plant
- Raw material (HDPE resin)

Figure 8 – Injection molding LCA boundaries



Source: elaborated of Elduque, Elduque, Javierre, Fernandez, & Santolaria, 2015

The integration of both analyses, with assumptions and simplifications, covers almost completely the whole process that components undergo to become finished products. Table 17 shows the impact categories that the production and the injection molding of HDPE affect, considering the quantities hypothetically saved in best and worst cases. Therefore, the table indicates effects on the categories caused by the processes for obtain 5.793 kg of finished product in the best-case and 2236 kg in the worst-case.

Table 17 - Impact categories of plastic

INPUT PARAMETERS			
INDICATOR	UNIT	WORST-CASE	BEST-CASE
Non-renewable energy resources			
- Fuel energy	kWh	19.600,00	50.700,00
- Feedstock energy	kWh	29.700,00	76.900,00
Renewable energy resources (biomass)			
- Fuel energy	kWh	497,00	1.290,00
- Feedstock energy	kWh	-	-
Abiotic Depletion Potential (ADP)			
- Elements	kg Sb eq.	0,00	0,01
- Fossil fuels	kWh	54.800,00	142.000,00
Water "cradle to gate"			
- Use = Withdrawal	kg	165.000,00	426.000,00
- Consumption	kg	71.300,00	185.000,00
OUTPUT PARAMETERS			
INDICATOR	UNIT	WORST-CASE	BEST-CASE
Climate change	kg CO_2 eq.	6.460,00	16.700,00
Ozone Depletion Potential	g CFC-11 eq.	1,43	3,71
Acidification Potential	g SO_2 eq.	9.580,00	24.800,00
Eutrophication Potential	g PO_4^{3-} eq.	2.680,00	6.950,00
Photochemical ozone creation potential	kg C_2H_4	650,01	4.343,50
Human toxicity potential	kg 1.4-DCB eq.	939,00	2.430,00
Fresh water aquatic ecotoxicity	kg 1.4-DCB eq	1.200,00	3.110,00
Marine aquatic ecotoxicity	kg 1.4-DCB eq	3.800.000,00	9.850.000,00
Terrestrial ecotoxicity	kg 1.4-DCB eq	7,71	20,00
Particulate matter formation	g PM10	8.880,00	23.000,00
Total particulate matter	g	9.640,00	25.000,00
Waste (only for polyolefin production, before treatment)			
- Non-hazardous	kg	2,86	7,42
- Hazardous	kg	2,08	5,39

In the first study related to HDPE production, monomer and co-monomer production dominate the effects on ADP, AP, EP, PMF, primary energy consumption categories and they contribute, almost equally with polymer production, to POCP category. (Co-)Monomer production refers to the monomer ethene but also to co-monomers including their pre-chain from the extraction of fossil resources to gate. Consumption of electricity, mainly from polymerization processes, impacts the climate change (GWP with a time horizon of 100 years) and ADP categories. Whereas pigments, catalysts, initiators, solvents, additives and their pre-chain are the second contributors of the potential depletion of abiotic resources (PlasticsEurope AISBL, 2014). The study is reliable and it express average results of the European industry considering different technologies, input materials and techniques. So, the error should be minimized for that part.

The second study, regarding the injection molding process, analyzes a specific set of technologies and equipment to perform that particular process. For instance, there is a substantial change of impacts according to the choice of injection molding machine type (hydraulic, hybrid or all-electric), and here we have considered all hybrids machines except for one all-electric. There is not information about the manufacturing processes of Plastico1 and Plastico2 products therefore it was mandatory to make a choice. Anyway, it is critical the selection of injection molding machines and their electricity consumption because, electricity is the most impactful variable. It accounts more than 90% of influence in every category, except for Abiotic Depletion category where the steel contained in the infrastructure is the principal influencing element (Elduque, Elduque, Javierre, Fernandez , & Santolaria, 2015).

3.3 CARDBOARD

There are substantial differences between the cardboard currently used for shipping boxes and the future cardboard: different formats, dimensions, annual requirements and material compositions. Therefore, in this section the current solution is going to be compared to the future two solutions, taken into consideration also in the economic assessment as best-case and worst-case.

Currently, the automatic packaging line with Alfa machines is using two formats of boxes: the high one (500x300x250mm) and the low one (500x300x125mm). Both formats are made of three sections and table 18 shows the details.

Table 18 – Current carton set sections: dimensions and weights

	Internal dimensions (mm)	**Basis weight (g/m²)**	**Weight (gr)**
Low cardboard belt	480x280x120	Between 597 and 600	113,40
High cardboard belt	480x280x243	Between 767 and 773	293,00
Bottom lid	490x289x48	Between 506 and 509	111,82
Top lid	490x289x48	Between 506 and 509	111,82

Source: technical files

Machines that are going to replace the current Alfa machines will use different boxes formats: the big one (500x300x300mm) and the small one (400x300x220mm). These formats do not have three sections but are made of a tray and a single lid placed on the top to close the box. Table 19 shows dimensions and weights of the future carton set of the two alternative supplies, from ImballingOne for the worst-case and from ImballingTwo for the best-case.

Table 19 – Future carton set sections: dimensions and weights

		WORST-CASE		BEST-CASE	
	Internal dimensions (mm)	**Basis weight (g/m^2)**	**Weight (gr)**	**Basis weight (g/m^2)**	**Weight (gr)**
Small tray	378x286x213	535	241,85	475	214,72
Big tray	478x286x293	535	359,08	475	318,81
Small lid	394x294x40	390	68,64	460	80,96
Big lid	494x294x40	390	89,70	460	105,8

Source: technical files

The real weight of cardboard (measured directly at the logistic center, with cartons ready to be load to the Alfa's case erector) slightly differs from technical files numbers mainly due to humidity. Therefore, in order to be consistent I decided to use the specifications, provided by suppliers, for every cardboard type.

Considering the differences between boxes specifications for the old and new systems and the annual requirements of production given by the same case calculation employed for the economic assessment, in table 20 there are the estimated annual saving of cardboard for both cases.

Table 20 – Best and worst cases cardboard saving

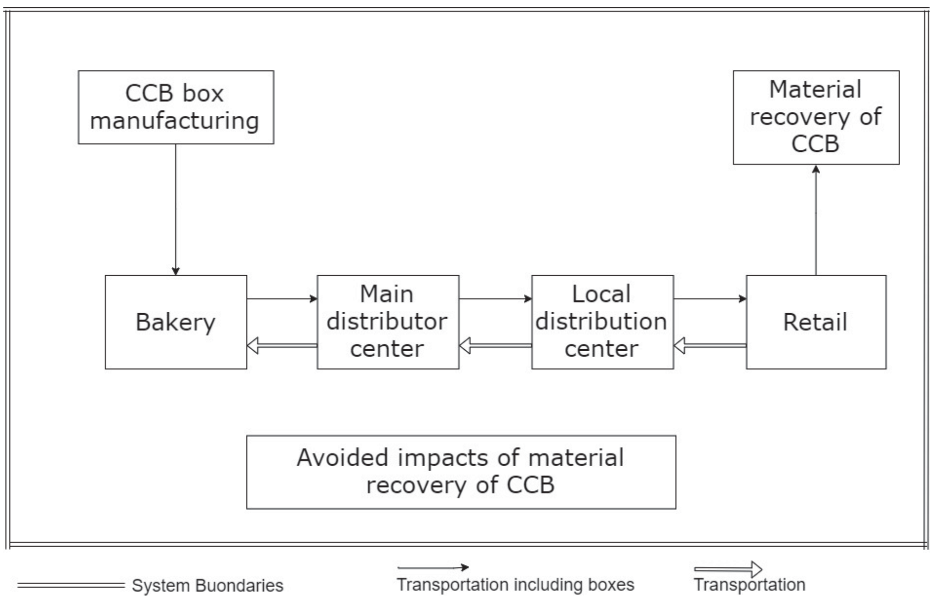
	Type	Unit weight (gr)	Annual quantity (units)	Annual cardboard consumption (kg)		Annual saving of cardboard (kg)
OLD SYSTEM	Low box	337,04	447.432	150.802	668.203	
	High box	516,64	1.001.472	517.400		
WORST-CASE	Big box	448,78	666.216	298.984	501.423	**166.780**
	Small box	310,49	651.996	202.438		
BEST-CASE	Big box	424,61	666.216	282.882	475.664	**192.539**
	Small box	295,68	651.996	192.782		

Even if the difference between the unit's weight of three solutions is little, the balanced use of small and big boxes of the new carton set leads to a huge saving of paper. For example, according to a study conducted by "Bureau of International Recycling" in one year a European consumes on average 137 kg of paper (Bureau of International Recycling, 2013). It implies the new system will save the annual consumption of more than 1.200 Europeans in the worst-case and 1.400 in the best-case. Similarly to what "The Economist" reported in its article, the optimization should be equal to a saving between 4.160 and 4.810 trees[5] (The Economist Newspaper Limited 2019, 2012).

[5] Considering a tree 40-foot high and 6-8 inches in diameter. Approximately 40kg of paper.

To express a technical evaluation using the LCA method, a study published by Science Direct in its Journal of Cleaner Production was taken as a reference and adopted to this case (Koskela, Dahlbo, Judl, Korhonen, & Niininen, 2014). The goal of the study was to compare the environmental impacts between the corrugated carboard box and plastic crate systems for bread delivery, from the bakery to consumer. It took into consideration the manufacturing processes of boxes from virgin materials and the delivery system (see figure 9). The functional unit of the product system was 8 loaves of bread delivered in one box weighs 190 g with dimensions 540x330x110 mm (Koskela, Dahlbo, Judl, Korhonen, & Niininen, 2014).

Figure 9 – Cardboard LCA boundaries



Source: elaborated of Koskela, Dahlbo, Judl, Korhonen, & Niininen, 2014.

The cardboard box used in the study is smaller and lighter than boxes used by Würth to deliver its products. Therefore, the comparison is based on the weight rather than number of boxes for trying to remove this problem.

Kilometers counted in the study for delivering the CCB boxes and bread, from the manufacturing site to the retail shops, are almost 2.000 km including a distance of 80 km by RORO ship is included. Instead, in our case the distance covered by ImballingOne's trucks for delivering boxes from Moudon (Switzerland) to Capena (Italy) and coming back is about 1.800 km. The transportation effects considered by the paper are slightly different respect to Würth case study: the distance is larger for about 200 km, it includes also sea transportation that usually has heavier impacts and modes of transport are different.

Table 21 – Impact categories of cardboard

Impact category	Unit	Worst-case	Best-case
Climate change	kg CO_2-eq.	769.000,00	888.000,00
Acidification potential	kg SO_2 eq.	5.480,00	6.320,00
Eutrophication potential	kg PO_4^{3-} eq.	333,00	384,00
Photochemical oxidant formation	kg NMVOC	6.500,00	7.500,00
Particulate matter formation	kg PM_{10} eq.	2.080,00	2.400,00
Fossil depletion	kg oil eq.	276.000,00	318.000,00

The predicted environmental impacts are showed in table 21. Transportation is the most significant contributor to all studied environmental impacts (Koskela, Dahlbo, Judl, Korhonen, & Niininen, 2014) and, as underlined above, distances covered in the Würth case are similar and really extended. The transportation variable lead to an underestimation of the best-case, because the transport will be reduced significantly considering that the supplier is only 100 km away from the Würth logistic center. In the best-case, impacts to be hypothetically removed are kilometers for the overall cardboard supply and not only those for the cardboard not consumed: from a supplier 800 km away to another distant only 100 km. The manufacturing phase of cardboard boxes has a moderate influence in comparison with the transportation, but more important is reusing the material because it helps to reduce its impact.

The normalization process, as defined in the ISO standard 14044, calculate the magnitude of the results of impact category indicators, relative to some reference information (Aymard & Botta-Genoualaz, 2016). In this case study the reference information considered were values of Europe and normalized results show that the lowest contribution of the whole LCA was to climate change category whereas the highest to the fossil depletion category (Koskela, Dahlbo, Judl, Korhonen, & Niininen, 2014).

To conclude, having an effective recycling system lower the impacts of manufacturing phases but, addressing management to take more eco-friendly choices about logistic concerns is even more important.

3.4 ELECTRICITY

As far as electricity is concerned, the same calculations made in section 2.4.2.5 have been taken into consideration here. To recap, table 22 shows the machine's power, working hours per day and working days per year considered for estimating the difference of electricity consumption between systems. On average, the annually energy saving amounts to 7920 Kilowatt thanks to the lower power required to run new machines.

Table 22 – Machines power and annual electricity consumptions

OLD SYSTEM				
Machine	**Power (kw/h)**	**WH/day**	**WD/year**	**Kw/year**
Case erector	16	11	240	42240
Case erector	16	11	240	42240
Lidding machine	5	11	240	13200
Lidding machine	5	11	240	13200
Total	*42*			*110880*
NEW SYSTEM				
Tray erector (400x300)	7	11	240	18480
Tray erector (500x300)	10	11	240	26400
Lidding machine (400x300x220)	11	11	240	29040
Lidding machine (500x300x300)	11	11	240	29040
Total	*39*			*102960*
OLD vs NEW (110880-102960)				***7920***

Würth has a contract with a private electricity provider for the current year (2019) that will be renewed in future and other suppliers might take its place. The energy mix provided by the supplier to the logistic plant based in Capena is composed of several sources, showed in table 23 (Customer service Engie Italy S.P.A., 2019).

Table 23 – Energy mix

Source	%
Renewable sources (wind, photovoltaic, hydroelectric and biomass)	24,09
Natural gas	47,49
Coal	19,13
Nuclear	4,39
Other sources	4,90

Having the energy mix available, it is possible to estimate the amount of CO_2 not produced by saving 7920 kilowatts of energy in one year. To estimate the amount of CO_2 arisen by the production of electricity from diverse resources, I investigated the literature to find a reliable and appropriate study. The World Nuclear Association published a report that brings together several studies of other organizations. The selected studies needed to meet some requirements such as the credibility of the source, an aligned definition of the "lifecycle" term and a unique unit of measurement for results presented. It includes data about nine different sources: lignite, coal, oil, natural gas, solar photovoltaic, biomass, nuclear, hydroelectric and wind. It is important to say that "Emission rates from power generation plants are unique to the individual facility and have site-specific and region-specific factors influencing emission rates”, as displayed in the report (World Nuclear Association, 2011).

Table 24 - CO2 emission of energy saved

Source	Energy Mix	Kwh	Kg of CO2e
Renewable sources (wind, photovoltaic, hydroelectric and biomass)	24,09%	1908	86,81
Natural gas	47,49%	3761	1876,84
Coal	19,13%	1515	1345,41
Nuclear	4,39%	348	10,08
Other sources	4,90%	388	346,75
		Total	**3665,89**

Table 24 shows the emission of CO_2 (in kilograms) thanks to the energy saving with new machines. Calculations are made by considering the average value of CO_2 emission per kwh reported in the study conducted by the World Nuclear Association, which considers also two other alternatives with minimum and maximum emission values.

CHAPTER 4 - THE INTEGRATED ASSESSMENT

In this part of the paper I am going to deal with the issue of monetization of environmental impacts. Monetization is a further step, in support of LCA, which consists in the conversion of physical units, results of the environmental assessment, into financial values. Several methods exist to do so, but all tend to follow the same process: after environmental impacts are assessed in physical units a conversion process into monetary terms is applied. It is an approach complex to implement because there is a wide set of parameters to consider while converting physical units into monetary terms (Morel, Traverso, & Preiss, 2018). Every parameter might change according to the geographic area of the study, political concerns, the surrounding environment, technical details as well as according to a degree of subjectivity.

This step makes the results clearer and more comprehensible to LCA inexperienced people who cannot otherwise understand the magnitude and importance of environmental indicators. Therefore, monetization helps the decision-making process of non-sustainability experts in three ways: understand the magnitude of environmental impacts, understand which pressures or stressors matter most and estimate future bottom line risks (Risz, Weidema, Reich-Weiser, & Hauschild, 2012).

The scope of the monetization process is to integrate the results into the economic assessment in order to understand the effects on the Net Present Value.

4.1 REVIEW OF MONETIZATION METHODS

After reading several case studies, publications and books about weighting methods or monetization, I came across multiple classification types of monetization methods. All these different approaches create confusion so, to focus the attention to a single methodology, I decided to take as reference the classification made by Göran Finnveden, who takes inspiration also from other sources. Finnveden is professor of Environmental Strategic Analysis at KTH Royal Institute of Technology and has published massively researches about the use and development of life cycle assessment and other sustainability assessment tools (KTH Royal Institute of Technology, 2020).

Before the classification is made, it is important to understand the concept of values relating to natural environments. The total economic value is the sum of the *use* and *non-use values*. The **use values** include both *direct* and *indirect* use values: an example of direct use value is the timber value of a forest, instead the indirect use value might be the recreation value of the forest, or the value of carbon fixation. **Non-use values** are linked to objects without assuming the intention of actually using them. They include *option use value*, *bequest value* and *existence value* (Finnveden, 1999).

The main distinction made by the author is between methods based on "Willingness-To-Pay" (from now on WTP) and methods that are not. The **WTP methods** focus their attention on the measure people has the intention to pay for avoiding something. Within WTP methods, a distinction between three different approaches is made: individual's revealed preferences, individual's expressed preferences and society's willingness-to-pay. The *individual's revealed preferences* method assumes that people reveal their preferences in market prices. Direct use values can be derived clearly from actual market prices (for example the market price of timber), instead indirect use values should be indirectly derived from them. The travel cost and the hedonic pricing methods are two examples for evaluating total use values. The *individual's expressed preferences* methods can derive non-use values from revealed preferences and the contingent valuation method is an example. It bypasses the need to refer to market prices by asking individuals explicitly to place values upon environmental assets. The *society's willingness-to-pay* is a method which derives the WTP from political or governmental decisions. An example could be studying the society efforts to avoid an environmental damage or studying the costs of reducing emissions up to a specific target. Another example of deriving a societal price is to look at green taxes that can be seen as society willingness to pay for that specific pollutant. Instead, **methods not based on WTP** are related to the avoidance of something but, it does not imply that somebody is willing to pay the cost of intervention. A further development of the society's WTP can be considered a method not based on WTP: the marginal cost for removing the pollutant up to a future target value cannot be considered a WTP method, because it is not clear if somebody is willing to pay for it, since the target is future and nobody has already paid for that cost (Finnveden, 1999).

Much attention must be paid to the comparability of results deriving from the methods explained above. Even if every method gives results in monetary terms, they describe different values and therefore results might not be comparable. For example, the total economic value measured by the contingent valuation method is typically an order of magnitude larger than the economic value measured basing on market prices, because the CVM includes also non-use values (Finnveden, 1999).

As already said while introducing the chapter, monetization helps the decision-making process of non-sustainability experts in three ways: understand the magnitude of environmental impacts, understand which pressures or stressors matter most and estimate future bottom line risk. According to Risz et al.: “Society increasingly requires organizations to internalize the societal costs of their impacts on the environment and human health through environmental regulations. Because of this, understanding the financial value that the scientific community puts on environmental impacts is a good starting point to understand the financial costs and risks that the company may have to bear down the road from regulation or resource scarcity. Additionally, the value of an organization’s externalities provides some insight into its associated reputational risk” (Risz, Weidema, Reich-Weiser, &

Hauschild, 2012). Therefore, firms should be aware of societies' concerns about environment and sustainability because governments are embracing all these interests and turning them into actual policies, interventions and taxes. We can just think about the European Green Deal, the commitment of the European Union and its citizens to tackling climate and environmental-related challenges that has the objective to transform the EU into a society with no net emissions of greenhouse gases in 2050 (Commission, 2019). Governments can impose corrective taxes or Pigouvian taxes to businesses to pay for negative externalities. In general, these taxes discourage the trade of environmental unfriendly goods through increasing prices. It implies negative effects on the economy but if governments reinvest the revenue generated into judicious fiscal policies (aimed also at enhancing their acceptability and effectiveness) the net economic as well as the environmental effects will be positive (Nguyen Thi, Laratte, Guillaume, & Hua, 2016).

All the considerations made just above are the reasons why I decided to monetize the environmental variables through green taxes. To recap, the reasons are the following:

- Green taxes can be interpreted as that value society (or governments through the democratic consensus bestowed on them by the citizens) gives to specific environmental assets, to damages caused by emissions or depletion of resources and so on.

- Moving up and internalizing forthcoming risks for the company. Risks are becoming more and more actual with the growing interest of the society about environment. For example, carbon taxation or other systems that use price signals provide the most powerful and efficient incentives for households and firms to reduce CO2 emissions (International Monetary Fund, 2019), therefore taxation is going to be the most "dangerous" and imminent instrument to mitigate pollution.

4.2 MONETIZATION OF CO_2 EMISSIONS

The first variable I am going to examine is the Carbon Dioxide (CO_2) and related emissions the new automated packaging system will save, compared to the old system.

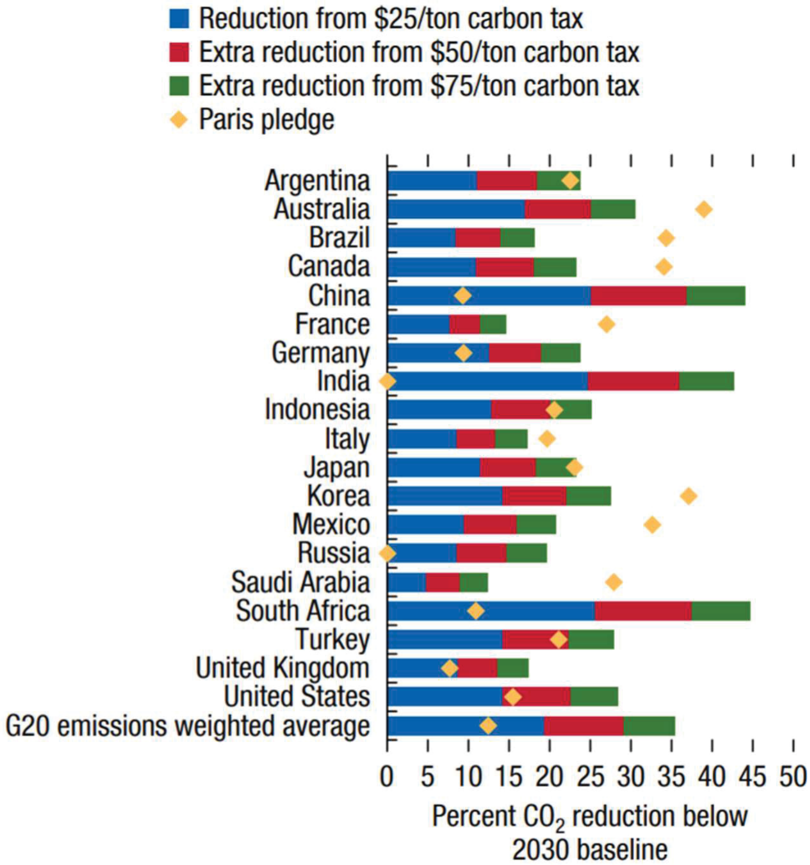
The Italian Carbon tax was inserted in the Financial Law for 1999 with the aim of reducing polluting emissions according to the commitments undertaken by Italy in Kyoto in 1997. It predicted growing tax rates on coal compared to fuel oil, diesel and natural gas but, as many law projects in Italy, it has never seen concrete implementation. Therefore, in Italy does not exist any carbon tax differently to other European countries. For example, Finland (1990), Sweden (1990), Norway (1991) and Denmark (1992) were the first countries to introduce such a kind of taxation and Netherlands (1996), Slovenia (1997), Germany (1998) and the United Kingdom

(2000) followed the trend. Switzerland and Ireland joined in 2008 and 2010 respectively (Galeotti & Lanza, 2015).

The International Monetary Fund (IMF) pays attention on climate change and mitigation policies indeed, it published a survey about this topic: the *Fiscal Monitor: how to mitigate Climate Change*. With that issue, the IMF argues that politicians have to act urgently to mitigate climate change and related problems. The Paris Agreement of 2015 goes on the right direction but, commitments undertaken by participating countries have been too much weak to match the safety levels recommended by scientists. The Fiscal Monitor affirms that, among all the mitigation strategies, carbon taxes are the most powerful and efficient tool because they guide the market to reduce energy consumption and to find alternative and environmentally friendly sources (International Monetary Fund, 2019).

Notably interesting is that the study analyzes the carbon prices countries must impose to implement their mitigation strategies and the tradeoffs with other mitigation instruments. In particular, the paper illustrates an analysis conducted to understand the extra effort needed by each country for attain mitigation targets by using *only carbon taxes*. Three scenarios are considered with three different tax levels and equivalent effects in 2030: $25, $50, and $75 per ton of CO2 (tax amounts are added to any existing tax in the country). Constant 2017 US dollars are considered throughout the analysis. Chart 10 shows results of the analysis for some selected countries (International Monetary Fund, 2019).

Chart 10 – Reduction in fossil fuel CO_2 from carbon taxes in 2030



Source: IMF staff calculations.
Note: Paris pledges indicate the percent reduction in CO_2 emissions below the baseline (that is, no mitigation) levels in 2030 if countries' mitigation pledges submitted for the Paris Agreement are met. Bars indicate the percent reduction in CO_2 emissions below baseline levels under carbon taxes with alternative tax levels. CO_2 = carbon dioxide; G20 = Group of Twenty.

Some interesting results follow (International Monetary Fund, 2019):

- The simulation reveals the highest tax level of $75 per ton of CO_2, if applied globally and combined with investment policies and reduction of CO_2 emissions from non-fossil fuels, lead to 2°C warming.

- Uniform carbon prices of $25, $50, and $75 a ton reduce CO2 emissions by 19, 29, and 35 percent, respectively, for the G20 group (with countries weighted by their future emission shares).
- whereas a $25 a ton price would be more than enough for some countries (for example, China, India, and Russia) to meet their Paris Agreement pledges, in other cases (for example, Australia and Canada) even the $75 a ton carbon tax falls short.

It is clearly noticeable from chart 10 Italy, even with a $75 carbon tax and considering all the assumptions made in that analysis, is not able to meet its Paris Agreement pledges about emissions reduction of CO_2. $75 should be the minimum carbon tax of ton of CO_2 Italy must apply to get closer to its commitments. Therefore, I decided to monetize that emissions through the carbon tax hypothesized by the analysis of the IMF for the following reasons:

- It reflects a long-term view of the problem,
- It is the output of a reliable analysis aimed at examining the problem globally,
- It is compared with international agreements undertaken by the most important countries having the objective to seriously solve or at least mitigate the problem of climate change that need urgent actions.

Taking this carbon tax as weighting factor to monetize CO_2 emissions can be considered a method not based on WTP because the target is future, still not adopted by any country and therefore nobody reveals its willingness to accept such a carbon tax.

In order to apply the tax to emissions saved there is the need to discount “constant 2017 US dollars” and to convert them into “current 2020 euros”. A possibility is to apply Consumer Price Indexes (CPIs) of United States of 2018 and 2019 and converting the result to euros through the exchange rate in force at the end of 2019 (Esposti, 2020). CPI of 2018 was 1,9% and CPI of 2019 was 2,3% (Coinnews Media Group LLC, 2020). The exchange rate in force at the end of 2019 was 1,1234 (Il Sole 24 Ore, 2020). Therefore, applying rules and figures mentioned above leads to a discounted tax of €69,59 per ton of CO_2.

Table 25 – Monetization of emissions of CO2

	Worst-case	**Best-case**
Paper	2.658,28	6.888,56
Plastic	6.460,00	16.700,00
Cardboard	769.000,00	888.000,00
Electricity	3.665,89	3.665,89
Total (Kg of CO2)	**781.784,17**	**915.254,45**
Tax per Kg of CO2 (discounted)	€0,06959	€0,06959
Annual Impact of the tax	**€54.408,10**	**€63.696,93**

The variables taken into consideration are the same of environmental assessment: paper, plastic, cardboard and electricity. I picked only the "climate change" category among the results of LCA simulations because it expresses the quantity of CO2 emission the variable causes. What stands out from the comparison of dimensions is that the cardboard variable has a clearly higher quantity, while the others are aligned. The CO2 emissions produced by the cardboard LCA are almost 120 times higher than those emitted by the plastic LCA, the latter in size. In the LCA of cardboard, the factor that affects most is the transport, which generates more than 90% of CO2 emissions. As already mentioned in chapter 3.3, kilometers traveled to transport the cardboard to the Capena logistics center are 1800, compared to the approximately 2000 considered in the LCA the difference is only 200 kilometers. Therefore, the comparison is consistent even if a slight overestimation of the impact should be kept in mind. Monetization of total issues leads to an annual monetary impact of €54,408.10 in the worst-case and €63,696.93 in the best-case. This is because the best-case considers greater savings in terms of emissions, therefore the impact in terms of money saved is greater. If the carbon tax were implemented, for example by the EU, Würth with the investment in new machinery would save an important sum every year. The assumed annual savings would be equal approximately to 2/3 of the savings caused by the elimination of filling materials consumption, the second most important in the economic evaluation. To make the idea even more, annual savings in the best-case would be able to repay the total investment in 15 years, without considering other savings.

4.3 MONETIZATION OF PLASTIC

The second variable to analyze is the consumption of plastic. The method I selected to monetize plastic consumption falls within the category of society's Willingness-To-Pay, in other words the WTP represented by political decisions of the Italian government in this case. On 30 December 2019, the law of 27 December 2019, no.160 was published in "Gazzetta Ufficiale", or the official source of knowledge of the regulations in force in Italy. 160. The law has as its object the "State budget for the financial year 2020 and the multiannual budget for the three-year period 2020-2022" and that therefore established, with a preventive accounting document what will be public expenses and revenue set for the following years. Among the various subsections contained in the law, number 634 establishes the tax on products consumption with single application that have or are intended to have the function of containing, protecting, handling or delivering goods. Items interested are made of, even partially, plastic materials with organic polymers of synthetic origin. Items must not be designed for more than one application during their life cycle or to be reused for the same purpose for which they were designed (subsection 634, L. 27th December 2019, àno.160, in the field of "Bilancio di previsione dello Stato per l'anno finanziario 2020 e bilancio pluriennale per il triennio 2020-2022").

Therefore, filling materials used by Wurth to protect goods inside packages fall into this category because they are composed of organic polymers of synthetic origin and are single-use. The subsection number 640 establish the tax at €0,45 per kg of plastic material (subsection 640, L. 27th December 2019, no. 160, in the field of "Bilancio di previsione dello Stato per l'anno finanziario 2020 e bilancio pluriennale per il triennio 2020-2022"). Subsections just cited will enter into force within two months after the issuing of a measure made by the Customs Agency, where it will define all operational procedures.

Table 26 – Plastic monetization

	Worst-case	**Best-case**
Plastic saving (Kg)	2.236	5.793
Annual impact of the Tax (€0,45 per Kg)	€1.006,20	€2.606,85

As we can see from table 26, the monetization of plastic consumption through a green tax, in this case called the plastic tax, leads to negligible results when compared with other factors from an economic perspective. The economic size of the impact is 4.7% in the worst-case and 4.9% in the best-case, compared to the reduced purchasing costs of the same amount of plastic (evaluated in chapter 2). It can be said that this monetization method underestimates the environmental impacts and their so-called social cost for the following reasons:

- The "plastic tax" has been subject to many oppositions and long political debates, which have limited its impact. Just until few months before the law was approved, the amount per KG was set at 1 euro. It would lead to more than a doubling of its impact,
- Like all green taxes, they should **gradually** become part of a country's tax system due to political and social resistance as well as to allow the market adaptation to that distortion. Therefore, the level of the tax taken as a weighting factor, should or could be subject to a gradual increase over time. Especially if the government "environmental" intent of the government is to eliminate the use of plastic wherever possible,
- It does not take into account the different types of plastic and therefore the related production processes throughout which they are produced. Therefore, the plastic tax does not consider the specific materials. and processes of each plastic type, which can have heavier or lighter environmental impacts.

4.5 OUTCOMES DISCUSSION

In this section monetization results will be integrated into the NPV analysis to understand the extent of the environmental impacts on the investment evaluation. The first subsection is dedicated to scenario number one characterized by a discount rate equal to 5,16%. That is higher in comparison to scenario number two, analyzed within the second subsection, which has the 2,84%.

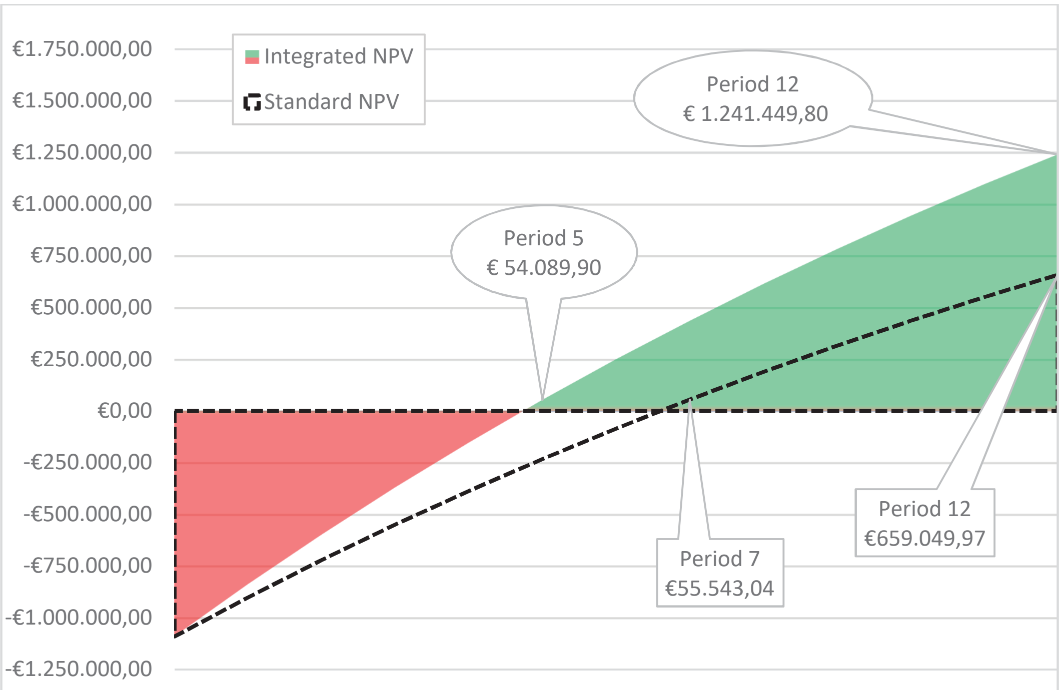
The integration helps to understand if the inclusion of social costs in economic analysis makes the investment more convenient or not. So, through the comparison between incremental costs and revenues (or decreasing costs) we will analyze the extent of the environmental impact, monetized through the consideration that community indirectly should or could give to the impact. As already mentioned before, there are only two variables monetized: CO2 and plastic consumption. Therefore, the impacts integration is partial and this might cause an underestimation of the social costs saved by the company's green investment. After calculating the annual impacts of the variables, it is possible to consider them as annual incremental cash flows and to simply insert them into the NPV analysis. The monetized environmental impacts will also be subject to the same discount rate applied to the other incremental cash flows.

4.5.1 SCENARIO 1

Chart 11 shows the NPV trend of the best-case with the integration of the monetized environmental variables, while the dotted line represents the trend of the NPV without the environmental variables. The first thing to highlight is the investment is recovered 2 years earlier (in 4 years and almost 9 months) because the first positive value occurs in period 5, compared to period number 7. The approximately

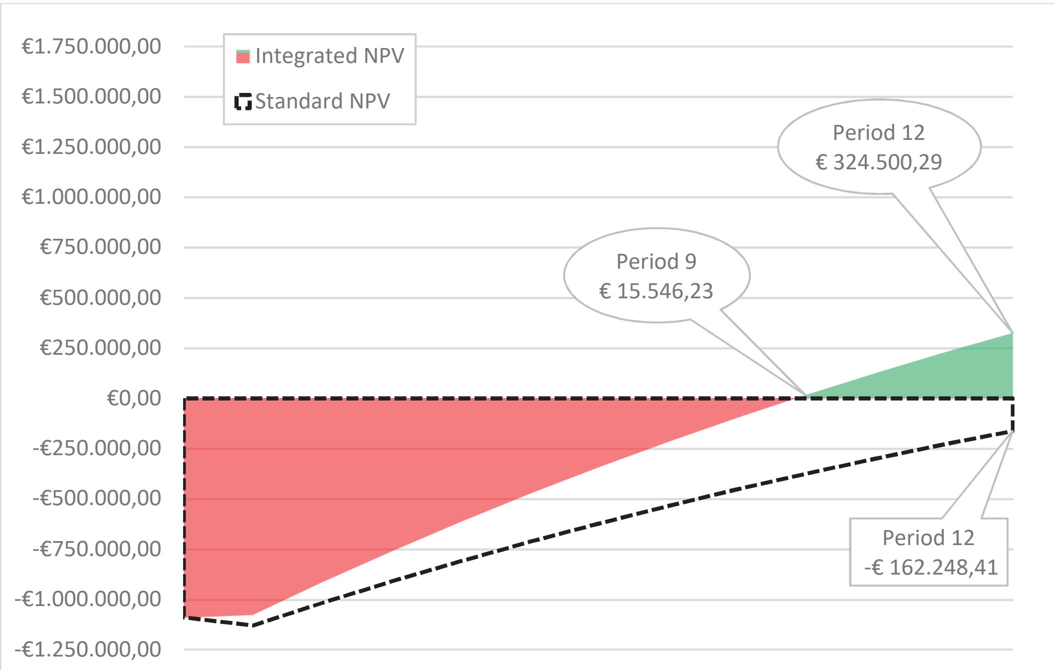
60 thousand euros of social costs significantly accelerate the recovery of the investment. In fact, at the end of the hypothesized life cycle of machinery, the NPV will be approximately 1,8 times the NPV which does not take social costs into account. The impact of social costs amounts to around 580 thousand euros, which also represents the potential savings for the company if the Italian government or the EU apply the green taxes on plastic and CO2 emissions: it is true that eventually the tax will not fall directly on Würth, but could still have an indirect effect of the same value on the price of goods and services that the company buys from third parties.

Chart 11 – Cumulative NPV scenario 1: integrated vs standard best-cases



If we look at chart 12, displaying the worst-case, positive effects of the integration are evident and the judgement changes drastically. The NPV becomes positive in period 9, then reaches more than 300 thousand euros at the end of the life cycle of the machinery. The result is much better than that obtained without taking social costs into account, which still in period 12 shows a negative NPV of more than 150 thousand euros. In this case, the integration makes the investment plausible, but not too convenient. Anyway, the company would be much more inclined to invest with a positive NPV even in the worst-case, because the investment would have a positive impact on the company and on the society. The overall impact of social costs amounts to around 480 thousand euros.

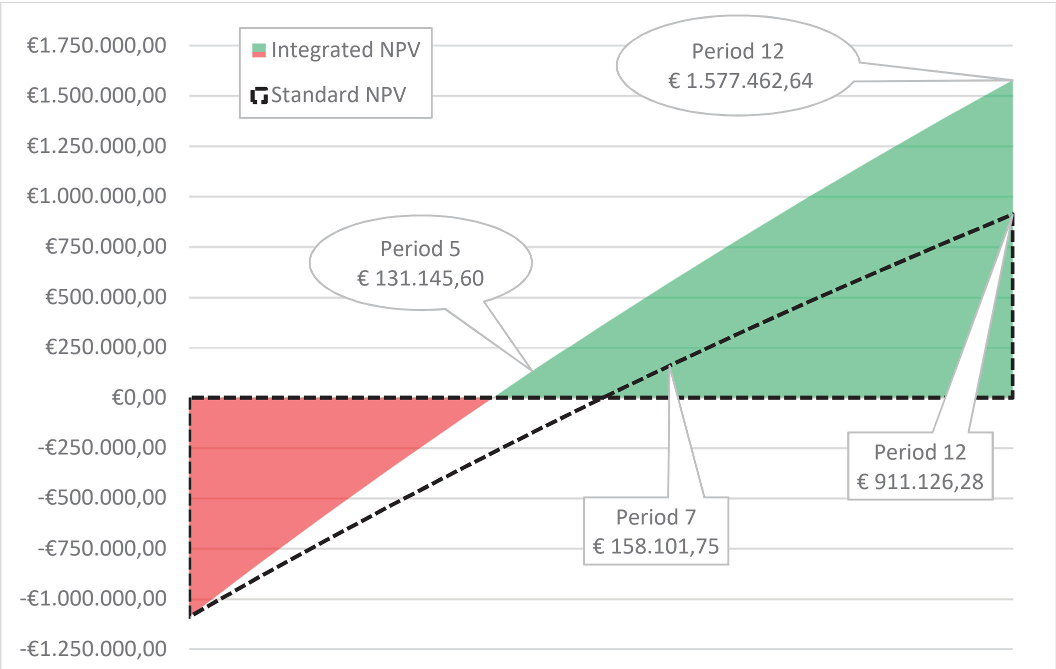
Chart 12 - Cumulative NPV scenario 1: integrated vs standard worst-cases



4.5.2 SCENARIO 2

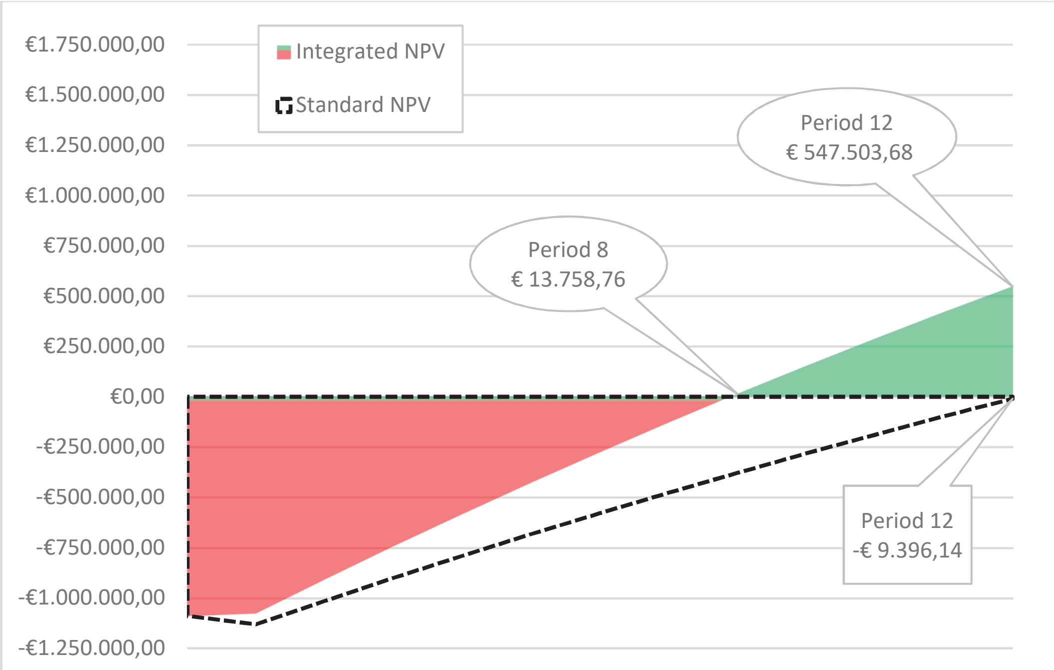
Looking at chart 13, which compares the best-cases of the integrated vs the standard NPVs, it is possible to notice how the break-even point is reached about 2 years earlier. Here, the effect of integration is even more evident because the lower discount rate accelerates the recovery that occurs after 4 years and just over 5 months. In period 12 the NPV is worth almost 1,6 million euros, with a net profit of almost 700 thousand euros over the same period as the standard NPV. The difference between the two NPVs of period 12 can be considered as the value of the social costs saved during the entire machinery life cycle.

Chart 13 - Cumulative NPV scenario 2: integrated vs standard best-cases



Even in the worst-case, effects of integration are clear and they impact even more heavily in scenario 2 than in the first, as can be seen from chart 14. Also in this case the standard NPV of scenario 2 shows a negative albeit small value at the end of the twelfth year. The counting of social costs means that the first positive value of the NPV occurs in period 8, and then ends up at almost 550 thousand euros in period 12. Here too, the integration of social costs radically changes the evaluation of the investment because even in the worst-case the company is able to recover the investment within an acceptable period and before the end of the life cycle of the machinery where there is a return (in terms of lower costs) equal to half of the initial investment. The overall impact of social costs at the end of the twelfth period amounts to around 560 thousand euros.

Chart 14 - Cumulative NPV scenario 2: integrated vs standard worst-cases



To conclude this part, some general considerations follow. If the company takes social costs into account and internalizes them into the economic evaluation, the investment becomes significantly favorable. Without considering all other impacts (deriving from the consumption of paper, cardboard and electricity for which it was not possible to find a value attributed by the society) the annual impact varies, between worst and best cases, from 480 thousand to 700 thousand euros. The new machines allow to provide the same service in a qualitatively superior way and with less use of material (or with the use of eco-friendly material). It decreases the damage to society: a significant amount of CO2 is certainly saved (especially if are avoided the kilometers traveled to transport the cartons from Switzerland to the logistics center), and the consumption of some materials can be eliminated.

CONCLUSIONS

The aim of this thesis was to give a preliminary assessment of the investment made by the company and its expected results in the years to come. The evaluation was carried out on two fronts: economic and environmental.

Concerning the economic front, the analysis is complete. An assessment based on data and concrete projections was possible on all factors, except for: return of image for the brand thanks to the more eco-friendly approach to packaging, renegotiation of contracts with couriers for less voluminous shipments, risks reduction linked to the possibility of purchasing cardboard from a single manufacturer and maintenance operations. About the return of image, once the machinery is installed and operative, it will be possible to carry out a market research through questionnaires to evaluate the users' satisfaction of the service. The renegotiation of contracts with couriers will always take place after the installation of the machinery because only after collecting data will be possible to determine the concrete decrease in the overall volume of shipments. In any case, variables just mentioned and left out from the economic evaluation have an insignificant weight compared to the others, for which making a reliable forecast was possible. For these reasons, the economic evaluation can be defined methodologically complete and reliable.

Looking at the economic results, we can conclude that the investment might have very positive implications and it depends on the production processes optimization. This potential is strongly oriented to become fact considering the structured company reality, advanced technologies and competent staff working on the project.

Regarding the environmental front, the analysis was less complete than the economic one. Due to the lack of information and/or specific technical skills, the evaluation of the glue, returns, maintenance and disposal of the machinery was omitted. To study the impact of the glue, specific information on its composition was required as well as skills and technical tools for measuring its impact. To conduct a reliable assessment of returns and their impact it would be necessary to collect data on actual post-installation results. While, for the maintenance and disposal of the machinery it would have been necessary to keep a detailed track of materials used and those dismantled. Instead, the variables analyzed led to overall beneficial results for the environment. The evaluation methodology of the same was consistent although not perfect, in light of the fact that studies taken as reference are carried out with different technologies and within different contexts. Works were accurately selected based on their comparability with the case studied in this thesis. Anyway, outputs can be considered reliable, plausible and with a positive impact on the investment in general, as reported in the dedicated section.

The integration of the economic with the environmental analysis was partial, as it was possible to convert only few environmental variables into monetary values. However, the converted variables are those for which society has a greater consideration than the others, also thanks to the awareness of their effects on the planet health. The integration results are important and they significantly change the overall investment judgment which becomes more convenient at a social level.

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