



Viability Analysis for the development of a Waste Plastic to Wax Technology plant

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Abstract

Plastic has become one of the fastest-growing man-made material mainly because it is traditionally produced with a single use objective. As its production continues to rise, plastic waste and lack of waste management is recognized as a major environmental threat. In this context, it becomes imperative to find alternative and innovative solutions for waste plastic.

This dissertation aims to study the viability of the development of a new technology within Europe, that focuses on tackling this issue. Following a Frequentative Thermolysis process, this technology allows the creation of multiple solutions, aiming at the production of highly valuable products from waste plastics. The analysis made focuses on wax as the target solution, a high demand and low supply product in the current market.

This paper starts by introducing the context of the opportunity with an overview of both plastic and wax market, creating a setting on which to build the financial model and investment structure. A DCF Valuation approach was used to value the financial return and the respective NPV of potential investors of this technology.

Lastly, the Environmental Impact of the technology and the production plants referred was calculated, accounting for the net impact of both the amount of greenhouse gas prevented by removing waste plastic from the environment and preventing it to be incinerated and the wax production impact.

Key Words: Environmental Impact, Transforming Technology, Waste Plastic, Plastic to Wax, Impact Investing.

Sumário

O plástico tem-se tornado num dos materiais sintéticos de mais rápido crescimento, muito por causa de ser tradicionalmente produzido com a finalidade de ser usado uma única vez. À medida que sua produção continua a aumentar, os resíduos plásticos e a falta da sua gestão são reconhecidos mundialmente como uma enorme ameaça ambiental. Neste contexto, torna-se imprescindível encontrar soluções alternativas e inovadoras para os resíduos plásticos.

Esta tese tem como objetivo estudar a viabilidade do desenvolvimento de uma nova tecnologia na Europa, que se centre na resolução desta questão. Baseado num processo de Termólise Frequentativa, esta tecnologia permite a criação de múltiplas soluções transformadoras, tendo como objetivo a produção de produtos de alto valor a partir de resíduos plásticos. A análise foca-se na transformação dos resíduos plásticos em cera, produto de alta procura e baixa oferta no mercado atual.

Esta tese apresenta em primeira instância o contexto da oportunidade de investimento, com uma visão geral do mercado de plástico e da cera, criando uma base para a construção do modelo financeiro e a estrutura de investimento. A metodologia de avaliação dos *Discounted Cash Flows* foi utilizada para avaliar o retorno financeiro e o respetivo NPV para potenciais investidores desta tecnologia.

Por último, foi calculado o Impacto Ambiental da tecnologia e das unidades de produção definidas, contabilizando o impacto líquido quer da quantidade de gases CO₂ prevenidos ao remover os resíduos plásticos do meio ambiente e evitando a sua incineração, quer o impacto da produção de cera através desta tecnologia.

Palavras-chave: Impacto Ambiental, Investimento com Impacto, Tecnologia Transformadora, Plástico para Cera

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1. Introduction

1.1. Problem Statement

Plastic production, consumption, and generation of waste are becoming increasingly relevant in the environmental impact paradigm, with an expected CAGR (2021-2028) growth of around 3,4% (Grand View Research Study, April 2021). It has become the fastest-growing man-made material and it is now recognized as a major environmental threat.

The expectations and worries towards this industry are high, including the expected increase in government spending, rise of European funds and their re-direction to this environment-related topic.

This study is an industry-focused thesis that explores the viability of introducing of a new plastic transforming technology - Plastic to Wax Technology, initially in European countries, to mitigate the negative impact that plastic waste currently has on the environment, by creating a compelling investment case. Thus, the study aims to answer the following research question:

Is it viable to invest in the development of a Plastic to Wax Technology plant?

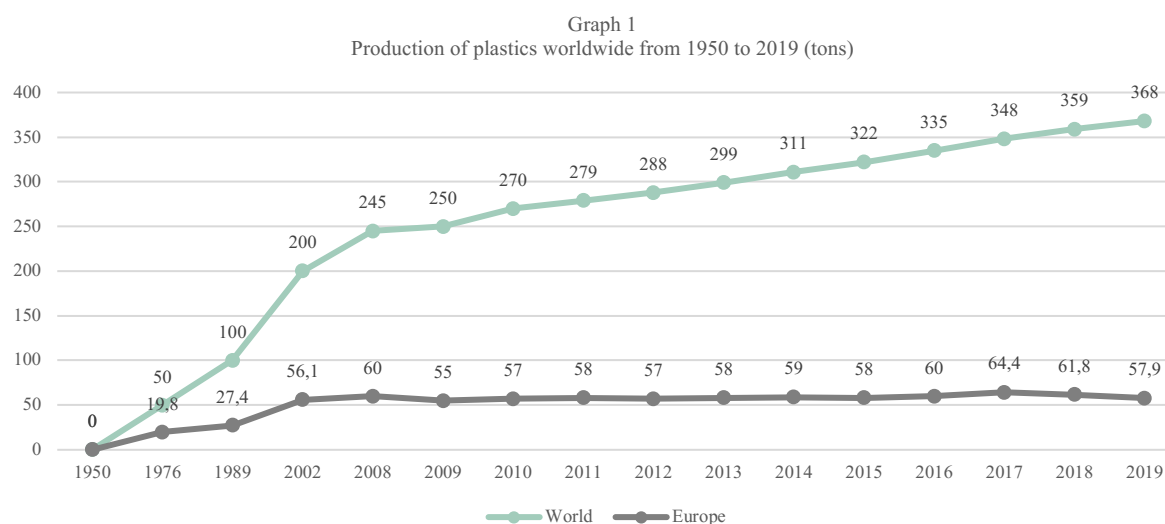
To achieve a constructive and comprehensive answer to the research question, this thesis is built upon a concise and suitable theoretical financial model, shown in full in the annexes (Table 7), derived from the production of plastic waste and recycling rate in each selected European country, as well as financial structure to be adopted by the owner of the technology patent (*The Company*).

The next chapters will introduce the context of the worldwide plastic industry and the wax industry as well as plastic production as an environmental problem. The technology and the transformation process will also be introduced, presenting the outline for the forthcoming sections. The Financial Model structure and investment approach will be detailed, followed by a calculation of the Net Environmental Impact of the technology and its production externalities, aiming to assess its viability.

2. Literature Review

2.1. Context of the Plastic Industry

Since the 1950s, when the industrial production of plastics began, the volume of plastics produced has increased exponentially compared to any other material. Over the last century, with the advancement of science and technology, plastics have been transformed into

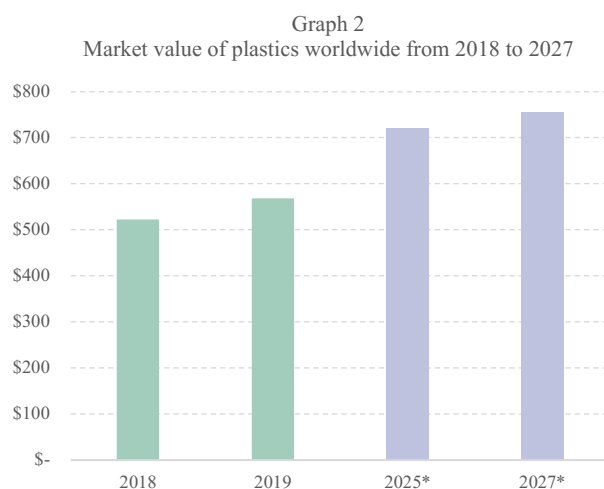


innovative solutions to society’s rising needs and challenges and can be found in components from all sorts of industries. Due to some core plastics’ characteristics like its ease of manufacture, low cost, impermeability, and their resistance to chemicals, temperature and light weight, plastics began to be used in a wide range of products and replaced several other materials, such as wood, paper, stone, leather, metal, glass, and ceramic (da Costa, 2016).

Given this versatility, functional properties, and low cost, which allows plastics to be used in a continuously increasing range of applications, it is not surprising that, according to the 2019 Plastics Europe report on the annual global production of plastics, 368 million tonnes of plastic were produced, presenting a growth of 2,5% compared to the 359 million tonnes in previous year. China is the leading plastic producing nation, with around 31% share of global production, followed by NAFTA Region, Europe, and the Rest of Asia, with 19%, 16%, and 20% respectively. When analyzing on a cumulative basis, the plastic production volume worldwide is expected to keep growing and reach 34 billion tons by 2050, (Plastics Europe, 2020).

The global plastic market size was valued at \$ 568.9 billion in 2019 and is expected to grow at an annual growth rate (CAGR) of 3.2% from 2020 to 2027, reaching more than 750 billion USD in the forecast period – Graph 2 (Statista, 2020). When looking at the future, it is expected

that by the 2050, this metric will have tripled in quantity and will account for a fifth of global oil consumption (Statista, 2020).



When accounting just for the EU28 European States, where more than 60,000 companies operate - most of them SMEs, the plastics industry had a turnover of more than 360 billion USD in 2018. The industry includes plastics raw materials producers, plastics converters, plastics recyclers, and plastics machinery manufacturers. This sector gives direct employment to more than 1.6 million

people in Europe and is the 7th ranked European industry in industrial value-added contribution, ranking at the same level as the pharmaceutical industry and very close to the chemical industry (Plastics Europe, 2020).

Regarding the distribution of plastic and its demand in 2019, in European countries, nearly 40% of plastics end-use was intended for packaging, followed by the Building and Construction sector and the automotive industry (Figure 1.).

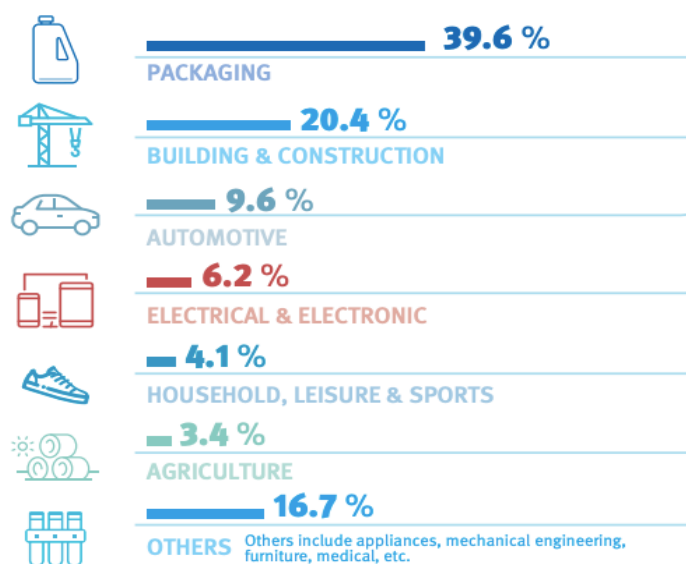
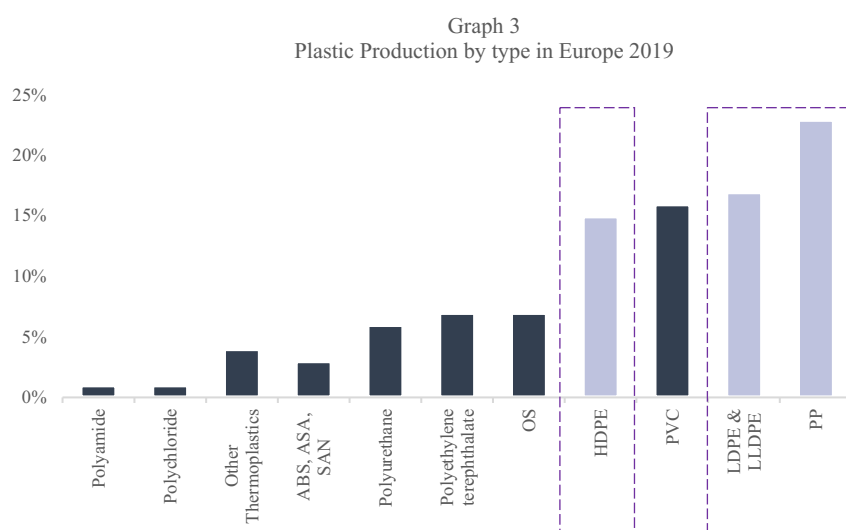


Figure 1 – European (EU28+NO/CH) plastic converters demand by segment in 2019, totaling 50.7Mt, according to Plastics Europe

2.1.1. Types of Plastics Distribution

The types of plastics that this thesis is focused on are thermoplastics since they are the ones most suitable for the technology hereby presented - Graph 3 (Plastics Europe, 2020). Thermoplastics are materials, normally plastic polymer, that changes its composition when heated or cooled.



When assessing the distribution of type of thermoplastics produced worldwide, Polypropylene (PP) is the most significant, representing around one fifth of global production. PP is used in a wide variety of applications such as most bottles, automotive industry, consumer goods, furniture market, between others, and it has the lowest density among commodity plastics. PP is followed by LDPE & LLDPE (17%) and PVC (16%), (Plastics Europe, 2020).

2.2. Context of the Wax Industry

The global wax market was valued at 9.9 billion USD in 2019 and is expected to register a CAGR 2020-2027 of 2,8%. The wax market produces approximately 5 million tons of wax yearly. In 2019, the market leader was Asia Pacific, with a 33,6% of the total market share. It is projected that this market share will continue to grow, and together with the Middle East, these two regions are going to be the largest and fastest growing over the forecast years, 2020-2027 (Grand View Research, 2020).

The demand for normal wax is expected to rise, in a wide range of applications, growing steadily at 2,8% per year. The main two drivers for this growth are: the cosmetics industry, growing at a global scale, will push the wax market to grow over the next seven years; increase commercial use from applications segments such as candles (representing 31,4% of total applications), packaging, coatings & polishes, tire, and rubber, between others (Grand View Research, Jun 2020).

The main producers of wax are oil refineries, which normally also produce crude oil. However, with the crude oil currently being priced higher per barrel compared to wax, producers focus on producing and selling fuel to achieve higher gains. This has resulted in a low supply of wax and consequently, a rise in its commercial price.

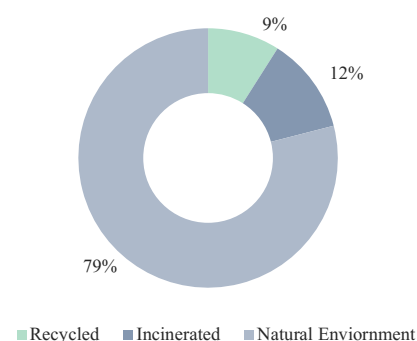
2.3. Plastic Environmental Impact

The same characteristics that make plastics highly desirable and versatile, are also those that provide them with negative impact in the environment. While the benefits of plastics are undeniable, their widespread use as well as their inherent resistance to biodegradation, ultimately leads to their accumulation in the environment. Most plastics do not degrade. Instead, they slowly fragment into smaller particles, referred to as microplastics. These particles have profound negative consequences for ecosystems, biota, and the environment, but also for the economy and human health¹. Microplastics have been found in the stomach of numerous live organisms, including all sorts of animals namely birds, turtles, dolphins, and whales, and in all sorts of processed foods. The health effects of the consumption of microplastics and chemicals associated are still unclear.

In addition, the chemicals used to improve some of the characteristics of plastics - known as *plasticisers* - can integrate into the environment and contaminate the soil and other organisms, potentially leading to bioaccumulation phenomena².

On a cumulative basis, an estimate of more than 7 billion tons of plastic waste have been produced. It is also estimated that plastic waste represents approximately 10% of the total municipal waste worldwide and that

Graph 4 - % of Plastic Waste per Destination



¹Source: Barnes, D.K., et al., Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society B: Biological Sciences, 2009

²Source: Jambeck, J.R., et al., Plastic waste inputs from land into the ocean. Science, 2015

80% of all plastic found in the world's oceans originates from land-based sources, which translates into some alarming statistics (Figure 2).

Figure 2 - Plastic Pollution Facts according to a European Parliament Committee, 2020

Plastic Waste Facts

- Only 9% of all plastic waste ever produced has been recycled
- About 12% has been incinerated, while the rest — 79% — was discarded, accumulated in landfills, dumps, or the natural environment (Graph 4)
- Every day, 8 million pieces of plastic reach the oceans, what translates yearly to between 4,8 and 12,7 million tonnes of plastic, equivalent to a garbage truck full of plastic dumped into the ocean every minute
- Plastic has been found throughout the Globe, including in remote and isolated locations
- Plastic waste is expected to increase 10x in the next 5 years

Plastics are also one of the most carbon-intensive materials to produce, accounting for 3,8% of global greenhouse gas emissions. It is estimated that the production and further incineration of plastic in 2019, emitted more than 850 million tons of greenhouse gases into the atmosphere, and it is expected to reach 2.8 billion tons by 2050 (Center for International Environmental Law, May 2019). For comparison, this value surpasses by almost double the amount of greenhouse gas emissions of the aviation sector. As mentioned in the previous sections regarding the plastic sector overview, the demand for plastic and its utilization in all sorts of products is set to rise, which will have the same growing effect on gas emissions. If the demand for plastic continues to grow at its current rate of almost 4% a year, emissions from plastic production will reach 15% of global emissions by 2050 (Nature Climate Change, 2019).

According to the Nature Climate Change study, about 61% of total plastic greenhouse gas emissions comes from the production and transport stage, due to the handling and transformation of resins using fuel. The further 30% is emitted at the product manufacturing stage, where the most of these emissions come from the energy required to power the plants that turn raw plastic materials into their final utilizations. The remaining 9% carbon footprint occurs when plastics have no longer commercial value and are thrown away. Incineration

releases the stored carbon and air pollutants in the plastic components into the atmosphere, which can be detrimental and damaging to human and animal health. It may seem that landfill disposal has a reduced contribution to greenhouse gas emissions. However, as plastics take centuries to degrade, 40% of which are incinerated, speeding up the release of the integrated carbon (Nature Climate Change, 2019).

The economic impact due to plastic waste and its handling is also expressive. The European Parliament Committee suggest an economic damage to the global marine ecosystems surpassing 11 billion EUR. In Europe, 630 million EUR are spent every year to clean plastic waste from coasts and beaches while the failure to recycle costs the European economy 105 billion EUR (European Commission, 2020).

A large fraction of plastics is designed to have a single use, discarded almost immediately, ending up in landfills and, ultimately, in the environment. After the first cycle of use, 95% of the value of the plastic material is lost, which is equivalent to about 80 billion USD annually. The cost of this externality is added to the cost associated with emissions of gases that contribute to greenhouse gas emission and negatively to the carbon footprint.

Plastic not only poses as an immediate pollution problem, but it also aggravates climate change. The Center of International Environmental Law (CIEL) 2019 report warns that the greenhouse gas emissions from plastic jeopardize our ability to keep the global temperature rise below 1.5°C. If plastic production stays on its current growth trajectory, by 2030, greenhouse gas emissions from plastic could reach 1.34 billion tons per year (CIEL, Plastic & Climate – The hidden costs of a plastic planet). The main reason for this volume of greenhouse gas emissions is because more than 99% of plastics are made from fossil fuels, both natural gas and crude oil. Also, because plastic production emits greenhouse gas at every stage of its lifecycle.

Consequently, there is a growing international determination to reconsider and evaluate the use of plastics at all stages of their life cycle. Government, businesses, and consumers are driving the increased focus on plastic waste recycling, because improvements on plastic legislation are needed to be able to better consider and address environmental and human health impacts. A variety of regulatory and legislative tools exists, aimed at controlling, reducing and managing the use of plastics. The European Commission proposed a Plastic Strategy with several targets for 2030, adopting a new circular economy action plan with several targets for sustainable growth, namely:

- Higher recycling targets (55% by 2030)
- Polluter pays-principle strengthened: Higher CO2 tax on incineration
- Strengthened Waste Framework Directive
- Requirements for recycled content in products
- Forthcoming EU Chemicals Strategy for Sustainability to develop regulation further
- Circular economy will become the norm for policymaking

All the targets enumerated pose an opportunity for new recycling and plastic waste management technologies to enter the market, capitalizing on the opportunities presented. The technology presented in this thesis, tackles the plastic crisis by removing yearly, per developed plant, 18 000 tons of waste plastic from the environment, creating a clear positive environmental impact.

3. Plastic to Wax Technology

3.1. The Company

The Company is a United States-based technology incubator that develops solutions for energy and chemical process industries with proprietary technologies. The business is based on the monetization of the technology solutions, amongst others, through a licensing process with entities who will build own and operate industrial plants that use those technologies.

John Hemmings, Vianney Valès and Filipe Marques are the Founders & Owners of The Company. For over 10 years they have jointly and successfully developed and transformed process technology concepts into commercial solutions in the alternative fuels and specialty chemical process industries.

3.2. The Project and Technology

The Company is currently developing multiple waste Plastic to Specialties solutions, derived from the same core process technology, named Frequentative Thermolysis and branded as the FQT Process™. The FQT Process™ can be used to created multiple solutions, aiming the production of high-valuable products from waste plastics, as stand-alone commercial plants or in combination with other processes or feedstocks, namely:

- PTRF – Plastic to Refinery Feedstocks (“crude products”)
- PTW – Plastic to Wax
- PTBO – Plastic to Base-Oil
- PTSM – Plastic to Specific Monomer (e.g., styrene)
- Combo with PTL – existing Plastic to Liquid plants for higher conversion of fuels/specialties
- Combo between waste plastics and other feedstocks, targeting RF, W, BO or even SM

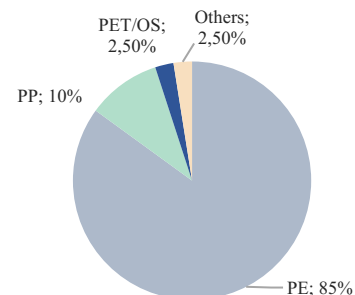
The Company’s first development solution is on waste Plastic to Wax (PTW), and it is the main focus and scope of the present master thesis. The commercial plants using FQT Process™ PTW solution are expected to be extremely competitive, with unleveraged IRR of more than 25%, depending on the country selected.

3.3. The Plastic to Wax Solution Process

The solution is based on a thermolysis under mild conditions in batch process. A thermolysis process is the thermal decomposition that requires an input of heat energy, pressure, and pre-determined temperature.

It consists of two stage process with a melter (at 200°C) and batch thermolysis at 350-400°C. Use of a suitable aliphatic solution reactant for plastic pumpability. The solution reactant is also consumed/transformed in the process. The products are more than 90% waxes (lightly branched and straight chain) and fuel gas to provide energy to the process.

Graph 5 - Plants Require Mixed Waste Plastics



Specification of feedstock prepared for reaction is around: 85% PE; 10% PP; 2,5% PET and 2,5% other mixed waste plastics (Graph 5).

The required equipment is similar to the one used in Plastic-to-Liquids (PTL) and in Wax upgrading plants, both of which the company is familiar with.

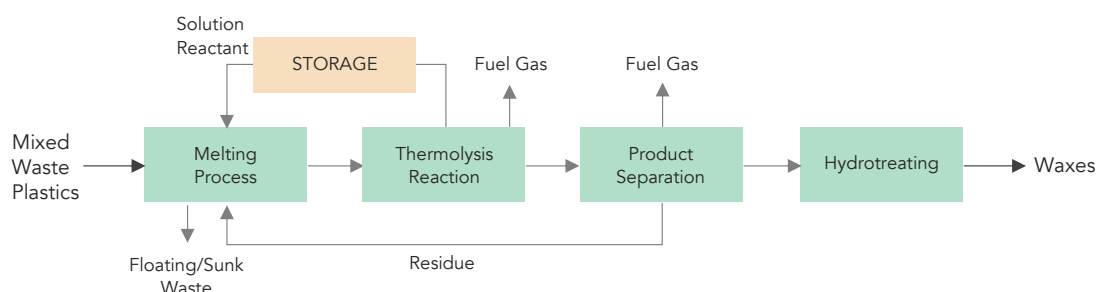


Figure 3 - Basic Transformation Concept

The desirable resins in the Mixed Waste Plastics (MWP) melt and mix in the melting stage. Less desirable materials not removed during bales preparation (PS, PET, PVC) are denser, higher melting and less soluble in a paraffinic and olefinic solution reactant and settle out in melter. Any heavy contaminant carried in the recycled residue (heavy wax) also settles in the melter. Partially degraded plastic (ultra-heavy wax) is recycled, carrying heavy contaminants with it which are also discarded with the "sinking waste" at the bottom of melter. Light contaminants (paper, etc., typically less than 2%) float in melter and are removed as required. Distillate, light wax and naphtha range material are typically used as the melter solution and

recycled to extinction and converted partially to high value heavy wax. Short path distillation is used to make narrower and more valuable wax cuts. Waxes are hydrogenated to improve odor and color and commercial value.

3.4. Potential Competitors

Worldwide, new players have joined the industry over time to capitalize on the substantial growth it has registered. However, most players have their processes' focus mostly on other Plastic-to-Liquid (PTL) solutions, not specifically Plastic to Wax (PTW). Therefore, comparing them financially may create a biased since all companies have different core businesses, deriving different sale and cost structures.

The following three companies presented, are the most relevant competitors when considering the technology plastic to wax, and the ones that can be better compared to The Company.

- **Trifol Resources:** Trifol is an Irish company that has developed and patented a process for turning landfill plastic into wax for use in a wide range of products. Trifol can convert end-of-life plastics into commercial waxes, ingredients for the production of synthetic lubricants, and liquid fuels as a by-product. It removes up to two tons of plastic waste for each ton of wax produced. The company can also produce wax ingredients for the production of synthetic lubricants.

- **Green Mantra:** Green Mantra is a Canada-based company, incorporated in 2010, produces value-added synthetic waxes, polymer additives, and other chemicals from recycled plastics. The company claims that it can achieve 100% conversion of plastics to wax. Very environmental driven with a number of different products and applications from asphalt roofing, asphalt roads, polymer processing and plastic composites.

- **Nexus Fuels:** Nexus Fuels is an American waste management and energy production company that has developed a commercial-scale process (Nexus Technology) for converting waste plastics into feedstocks for plastics production and fuels, which can be further refined into a full range of products. It does have the technology to turn plastic into wax, but their core business is fuel.

The companies presented may pose as potential competitors, since they also have a technology capable of transforming plastic into wax. However, they currently compete at a different market and focus on different selling products, mainly on selling fuel deriving from its higher commercial price.

3.5. Business Opportunity

The Plastic to Wax technology's business implementation and potential business captures three complementary opportunities, framed in today's reality and economic future perspective, namely:

1. The increase in demand for high quality waxes from recyclable feedstock

- Both plastic and wax are correlated in terms of growth and production since wax is one of the feedstocks used in the plastic production process and they both can be derived from fuel. That way, as the plastic sector experiences growth, the wax sector and demand grow accordingly
- There is a growing imbalance in market supply and demand, in particular of high-quality waxes, growing constantly in the past few years for more than 3% (Grand View Research, Jun 2020).

2. Vast amounts of waste plastic in Europe with no management strategies

- The European Union has banned all non-recyclable plastic waste being shipped to developing nations. Stricter measures have been adopted on the export of plastic waste from the EU to OECD (Organization for Economic Co-operation and Development) countries and intra-EU shipments of plastic waste.
- Another example, from January 2018, is China, who banned the import of waste entirely, in order to stop the crushing flow of plastic waste.
- These bans have a profound impact throughout the world, namely developed countries with a high volume of plastic consumption. These western countries are suddenly confronted with vast amounts of such waste with no management strategies to deal with them.

- These bans highlight the urgent need to restructure existing recycling systems and policies on the production of plastic and its disposal.

3. Recycle and Environmental European targets to 2030

- Under the new European targets, the European Commission fixed a new target of 55% recycling of plastic packaging waste by 2030 (Plastics Europe, 2020)
- The new policies encourage the development of waste policies which promote the most efficient and sustainable recovery or recycling solutions whilst also diverting all plastic waste from disposal (Plastics Europe, 2020)
- More than 250 million EUR for research and development linked to plastics in the circular economy. An additional 100 million EUR by 2020 will be devoted to financing priority actions, including more efficient recycling processes and the removal of hazardous substances and contaminants from recycled plastics (European Commission, 2020).

4. Financial Model Structure and Analysis

This analysis undertook an excel-based financial model which entailed the elaboration of an instrument that performed detailed financial and economic analysis and prediction for the development of commercial plants of the technology presented, accessing the total plastic supply of different countries, and returning respective plant cash flows. The model can now be used to define assumptions and unlock decisions on the project specifications.

4.1. Country Assessment

Each country was chosen having into consideration (1) Country in Europe; (2) The quantity of plastic produced in the analyzed country; and (3) Its recycling rate.

The countries that were selected to be included in this viability analysis were Portugal, Spain, United Kingdom, Germany, Sweden, Austria, Switzerland, and Belgium.

Portugal and Spain were chosen given their geographical proximity and knowledge of the recycling sector. Seven interviews with sector specialists were made to have a clear vision of the market, its structure, and their insights on the viability of this technology. The United Kingdom, Germany and Sweden were chosen given their high volume of plastic production and recycling rate. The last three countries were select due to their national recycling targets and policies, set more aggressively than in the rest of Europe.

Country	Plastic Production (tons)	Recycled (tons)	Recycled (%)
PORTUGAL	600 000	72 000	12,0%
SPAIN	758 400	328 387	43,3%
UK	2 260 000	1 039 600	46,0%
GERMANY	3 000 000	1 683 000	56,1%
SWEDEN	1 258 000	616 420	49,0%
AUSTRIA	920 000	494 960	53,8%
SWITZERLAND	1 000 000	537 000	53,7%
BELGIUM	610 000	207 400	34,0%

Table 1 – Tons Plastic Production and Recycling rate per selected country (2018)

The data presented in Table 1 resulted from desk research work directed for this paper. Plastic production refers to the yearly tonnes of plastic manufactured in each country. The data collected on plastic production and recycling rate has a margin for error since used existing reports and the type of data are not consistent and annualized for every country selected.

However, even if shown values are not 100% accurate, they can be used to assess the volume and recycling efficiency of each one of the selected countries.

4.2. Plant's Capacity Definition

To develop the Business Plan and assess the investment return for the potential investor, it is assumed that every plant has the same size and capacity. Each commercial plant has a total area of 5 acres and a total capacity for around 18 000 tons of waste plastic per year.

Information about the Plant	
Plant Capacity	18 000 tons
# employees	25 employees
Plant Area	5 acres

Table 2 – Key characteristics of each commercial plant

For the purpose of guiding the reader through the structure and modelling of each plant's financial outlook and viability, **Portugal** is used as an example for this analysis.

To assess the viability of one plant in Portugal, the assessment of the quantity of plastic produced in Portugal is needed, as well as its recycling rate. In this case, the plastic production reaches 600 thousand tons of plastic annually, while the recycling rate was 12% in 2018 (Agência Portuguesa do Ambiente, 2018). The assumption made for plastic production growth is +2% yearly and for its recycling rate is +1% yearly. This assumption derives from interviews with sector specialists.

The second step is to distribute the total quantity produced per type of plastic, following the assumption taken, that states that the standard European distribution per type of plastic is the same in every country. When the total quantity of plastic recycled in Portugal per type is accessed, it is possible to determine the available

Plastics Demand in Portugal	
Annual Waste Plastic Production (tons)	600 000
<i>Yearly Growth Assumption</i>	2%
Annual Recycled Rate (%)	12%
<i>Yearly Growth Assumption</i>	1%
Annual Plastic Collected	72 000
European Plastic Demand per Type (%)	
PP Plastic	19,30%
HDPE Plastic	12,20%
LDPE Plastic	17,50%
PET	7,70%
Others	43,30%
Country's Total Plant Capacity	
PE (85%)	21 384
PP (10%)	2 516
PET (2,5%)	629
Others (2,5%)	629
Total Mixed Waste Plastic	25 158
# Possible Plants in Portugal	1,40

Table 3 - Portugal's Plastic Production and Capacity

quantity for purchase. For 100% capacity, the plant requires an annual batch of 18 000 tons of plastic, following the percentages described above. In this case, there is only enough plastic for 1,4 plants in Portugal, what results in an actual capacity for development of 1 plant in Portugal, regardless of the assumption taken (Table 3 – Full table in the Annexes).

A 10-year forecast of annual waste plastic was made for every country, as well as annual recycling rates, deriving from assumptions made before. When doing the forecast for the next decade, Portugal will not have enough plastic production and recycling volumes to develop a second production plant, only reaching 1,88 possible plants in year 10.

	Maturity Year							
	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
# Plants	0	0	1	1	1	1	1	1
Production Capacity	0	0	30,0%	75,0%	100,0%	100,0%	100,0%	100,0%
% Country Plastic needed for this technology		0,0%	20,2%	49,1%	63,5%	61,7%	59,9%	58,1%

Table 4 – Plant’s Production Capacity per year

In the first year of production (year 1), the plant is still under development, so it does not have any production capacity (=0%). In the second year (year 2), we assume that each production plant only reaches 30% of its full capacity and 75% in the third year. From the 4th year onwards, the plant can work at full capacity (100%) – Table 4 (Full table in the annexes).

Having these two factors into consideration, both the total amount of quantity available per type of plastic in Portugal and the plant production capacity in each year, we can calculate the quantity of plastic needed for this technology to run and the percentage it represents in each country. For Portugal, as seen in Table 4 above, in the second year, for only 30% of production capacity, the plant would need 20,2% of all the plastic available in Portugal for its functioning. This implies that as it is today, 20,2% of the total amount of plastic recycled, that is currently being directed to other recycling and waste management entities, should be re-directed, and be bought as feedstock for this production plant. This will require a commercial plan and also an aggressive purchase price, that should be higher than potential competitors.

4.3. CAPEX

The initial investment needed for the development of the production plant, accounting for the construction of the factory, purchase of the necessary machinery and the CAPEX items identified in the annexes, amounts to a total of 26,3 M USD (more precisely, 26,275,639 USD).

This value is distributed along the 4 first years of development according to the following percentages stated below: Year 0 = 30%; Year 1 =60%; Year 2 = 5%; and Year 3: 5%. The latter 2 years represent costs for finetuning of the operation.

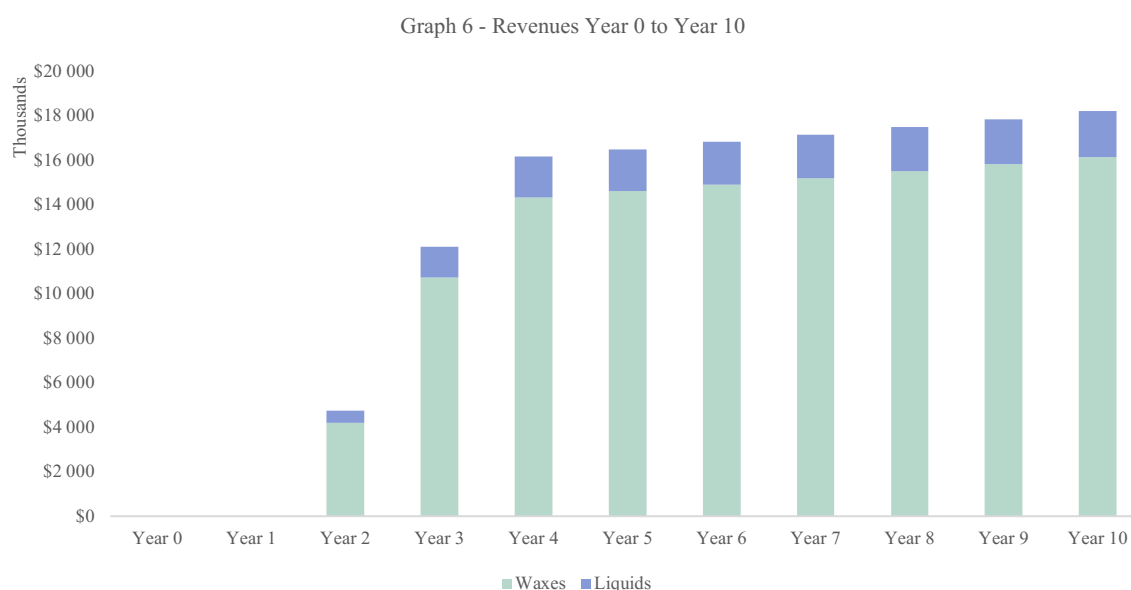
BP - 1 Plant	Year 0	Year 1	Year 2	Year 3
CAPEX	\$ (7 882 692)	\$(15 765 383)	\$ (1 313 782)	\$ (1 313 782)
Distribution (%)	30%	60%	5%	5%

Table 5 – CAPEX Distribution per year

This CAPEX investment, and the distribution presented, the payback period is 5 years of production (Year 0 and Year 1 are not considered).

4.4. Revenues

The production plant’s main revenue stream is the selling of wax, from the transformation of waste plastic to wax. However, they also have a second stream of revenues, selling liquids (naphtha, distillate), also coming from the same plastic to liquid technology. This results from part of the batch of collected waste plastic, that does not fit into the needed criteria for the PTW process, so it is transformed into liquids. Both these revenue streams were personally assessed by The Company’s group of scientists, having into consideration their knowledge and insights of the market.



The revenues should increase as the plant’s production rate gets closer to its full capacity, in the cruise year, year 4. For the following years, revenues remain the same, only adjusting for inflation (2% per year). Considering the plant capacity, 18,000 tons of waste plastic per year, the revenues for the selling of wax reaches 14.3 M USD in the cruise year (88,6% of total sales), while the revenues for the selling of liquids reach 1.8 M USD (11,4% of total sales) in the cruise year.

4.4.1. Average Selling Price of Wax

The average selling price of waxes was set having into account the insights from *The Company* scientists, at 1 500 USD per ton. Based on specialists’ insights, the average price for wax in Europe is 1,43 cents/kilogram, around 1 430 USD per ton. If we consider retail prices, likely it would be priced higher, around 1,89 cents/kilogram, what translates into 1 890 USD per ton. It is assumed that wax selling prices are adjusted for inflation after the cruise year, applying a 2% yearly increase, to account for the compounding effect.

4.4.2. Average Selling Price of Liquids

Considering the same premises as above, the price set for the selling of liquids is 623 USD per ton, also adjusted for inflation after the cruise year.

4.5. Operating Expenses

4.5.1. Fixed Costs

The rubric of fixed costs contains Maintenance costs and License & Service fees, respectively accounting for 656,9 thousand USD and 575,6 thousand USD annually.

4.5.2. Labour Costs

Each model plant has 25 working employees, divided along the operation and the supervisory of each team and working with 3 shifts (Table 6). Labor costs will vary from country to country due

	3 Shifts	1 Shifts
Operators	15	5
Shift Supervisors	5	2
Op. Manager	1	1
Maint. Manager	1	1
General Manager	1	1
Sales	2	2
<i>Total</i>	25	12

Table 6 – Plant Employees per position

to differences in salary payments. Considering Portugal as the base case, for the all the presented employees, the Labour Costs reach 1 M USD in the cruise year, after which will only increase from inflation rate.

In the first year of production, this cost rubric is cut in half, accounting for just one shift. The structure and management stay constant, while it is assumed that the factory, working only at 30% capacity, will work with 5 operators (1 shift).

4.5.3. Production Costs

The production costs are variable costs, depending not only on the production capacity rate in each year, but also on the amount of plastic bought. It includes the waste plastic purchase costs, the costs of sales, costs regarding catalyst, hydrogen, and power, as well as production add-ons like chemicals, cooling water, and others. The total production costs amount to 3.3 M USD per year, only adjusted for inflation after the cruise year.

Being the production capacity of the plant, 18 000 tons per year, it is assumed that there is a steady inflow of plastic over the year, amounting to this value. The production plant will have a storage facility, already represented in the cost above.

4.5.3.1. Waste Plastic Purchase Price

When accessing the purchase price per ton of mixed waste plastic, interviews with market specialist were made alongside a base desk research. The mixed plastic can have a range of prices through European countries. This range follows a downward trend, in some cases reaching a negative price. However, for the purpose of this paper and having in consideration the benchmark done and the insights from people in the sector, the price set for the business model was 100 USD per ton. This value accounts for 85% of PE, 10% of PP and 5% other types of mixed plastic, already including transportation and logistics costs. For the plastics purchase price, the values will not be adjusted for inflation over the forecast period since waste plastic prices tend to zero.

The stated purchase price is higher than the European average, which, along with incentives for the reduction and handling of waste plastic, is tending to a negative cost. Nonetheless, to account for potential externalities and keep the model conservative, the cost of waste plastic was set at 100 USD.

4.5.4. Plant Royalties

The plant royalties represent payments made by the investor to *The Company*, in exchange for the use of the intellectual property (IP) with reference to the plant’s technology. For each specific production plant, the royalties rate determined was 1% of the annual revenues generated by all active plants. There can also be an additional royalty, only applicable if the investor is not the plant developer. In that case, he will charge a 4% of annual revenues to the plant developer.

4.6. Business Plan Development

To reach a financial valuation of this technology, the Discounted Cash Flow (“DCF”) model was used, as it was considered the most accurate valuation technique to determine the fair value of each commercial plant. In this model, the value of an asset is the present value of its expected future cash flows, discounted back at a rate that reflects the riskiness of these cash flows (Damodaran, A., 2006).

In the DCF model presented, we conducted a two-stage valuation analysis, combining the Forecast Period of 10 years with a Perpetuity Value, to reach the true value of the investment. In performing each plant’ valuation, several assumptions had to be made, mainly to create forecasts regarding the evolution of the production capacity and sales growth (Table 7 in the presented in full in the Annexes).

Considering all the information stated before, it is possible to calculate the cash flow of one commercial plant in Portugal, following the structure presented in Table 6 in the Annexes. The tax applied also changes from country to country, with 22,5% applied in Portugal.

WACC Calculation	
Beta	1,05
Equity Risk Premium	8,46%
WACC	8,88%

Table 8 – WACC Calculation Metrics

To compute the discount percentage of the Cash Flows, the WACC (Weighted Average Cost of Capital) was calculated following a standard formula based on public information extracted and

based on market insights. The risk associated with this specific project and the market it is inserted is also reflected on this value, represented by the beta and the risk premium percentage used (values extracted from Damodaran data base, in March 2021). Additionally, the discount

rates considered in the analysis reflect current market conditions and affect the cash-flow projections and sensitivity analysis depicted further in this thesis.

The beta used for the calculation of the WACC discount rate was 1,05, accounting for the unleveraged beta of the industry. The equity risk premium used was 8,9%, for Portugal (Table 8).

WACC	8,9%
DCF 10y	11 465 692 €
DCF Perpetuity	34 531 011 €

In the case of one production plant in Portugal, the sum of all discounted cash flows for the investor would be 45.9 M USD with a 10-year IRR of 28%. The respective payback for one plant in Portugal equals 6 years. The DCF for the other countries selected varies, as well as the IRR, presenting values between 26% and 31%.

DCF	45 996 703 €
IRR 10Y	28%

Table 9 – WACC Calculation

Given that we can secure the quantity of waste plastic needed, with the gross margin of the business (79% in the cruise year), and the high supply volumes of the main raw material, the return on capital is attractive.

4.7. Country Discounted Cash Flow Comparison

To estimate the investment strategy and the investor total discounted cash flow, the development of 7 production plants was considered, located in the 7 different selected countries. The countries selected to allocate each production plant were chosen regarding its country plastic availability and capacity, the recycling market structure and labour costs associated (maturity in year 4) – Full Table 10 in Annexes.

The table in the annexes, with all the key financials from the selected countries, shows that the country with the highest IRR, with 31%, is Switzerland, posing as an attractive target. Also, given the high volume of plastic available in this country, the process of purchasing the waste plastic would be facilitated, since one plant would only need 8,5% of all the national plastic available (compared to more than 63,5% in Portugal).

On the other hand, with the lowest IRR of 26%, are both Sweden and Belgium. These countries are not so attractive in terms of financial return compared to the Switzerland and the others. However, leveraging national incentives for recycling rates, cuts in taxes and European funds targeting these geographies, these return rates could increase significantly.

	Portugal	Switzerland	Belgium	Sweden
% Country Plastic needed for this technology	63,5%	8,5%	22,1%	7,4%
BP - 1 Plant	Year 4	Year 4	Year 4	Year 4
Waxes	\$ 14 044 500	\$ 14 044 500	\$ 14 044 500	\$ 14 044 500
Liquids (naphtha, distillate)	\$ 1 808 569	\$ 1 808 569	\$ 1 808 569	\$ 1 808 569
Total Revenues	\$ 15 853 069	\$ 15 853 069	\$ 15 853 069	\$ 15 853 069
Fixed Costs	\$ (904 038)	\$ (904 038)	\$ (904 038)	\$ (904 038)
Labour Costs	\$ (1 046 400)	\$ (2 616 000)	\$ (2 616 000)	\$ (2 616 000)
Variable Costs	\$ (3 312 191)	\$ (3 312 191)	\$ (3 312 191)	\$ (3 312 191)
Plant Royalties (3%)	\$ (475 592)	\$ (475 592)	\$ (475 592)	\$ (475 592)
Total Operating Expenses	\$ (5 738 220)	\$ (7 307 820)	\$ (7 307 820)	\$ (7 307 820)
EBITDA	\$ 10 114 849	\$ 8 545 249	\$ 8 545 249	\$ 8 545 249
Tax	\$ (2 453 202)	\$ (718 681)	\$ (1 960 039)	\$ (2 333 379)
EBITDA - Taxes	\$ 7 661 647	\$ 7 826 568	\$ 6 585 210	\$ 6 211 869
WACC	8,9%	5,5%	6,4%	5,5%
DCF 10y	10 226 053 €	16 742 724 €	8 782 198 €	8 619 807 €
DCF Perpetuity	30 030 856 €	72 129 725 €	46 622 719 €	57 193 780 €
DCF	40 256 909 €	88 872 450 €	55 404 917 €	65 813 587 €
IRR 10Y	28%	31%	26%	26%

Table 10 – DCF Comparison between selected countries (Full table in the Annexes)

4.8. Financial and Investment Analysis

The Company is asking the investor for an initial investment of 2.7 M USD for the development of a demonstration unit. It is the investor's decision if he wants to develop the commercial plants if the technology is validated at an industrial level.

If that is the case, additionally, The Company is also asking for yearly royalties regarding the technology IP (1% of total revenues of each commercial plant developed). The duration of the IP considered was 7 years. After this period, the IP royalties are no longer charged by The Company.

Regarding the commercial plants, in terms of investment strategy, there are two possible scenarios:

Scenario 1 - The investor is the plant developer. This means that the investor will oversee the developing of the construction plants and management of them. In this first scenario, there would be no plant royalties, considering that the investor will receive the revenues in

full. If this was the scenario, the investment opportunity presented would become more attractive in terms of return rate.

Scenario 2 - The investor is **not** the plant developer. The investor will hold the patent for this technology and concede it to other plant developers, that will have to pay 4% of total revenues to the investor.

The Discounted Cash Flow model in this case, was calculated considering that the potential investor was not the plant developer. That way, the investor will receive a yearly sales-based royalty of 4%, for each plant developed.

The number of production plants grows every year, reaching in year 6 the defined amount of 7 plants. The plants should be located in the countries selected before. For this financial model, it was considered that in total there would be 7 plants, one in each of the selected countries. It is assumed that every plant takes 2 years to be fully developed.

The initial investment value to be paid to *The Company* amounts to 2.7 M USD, distributed in two payments in different time periods. The first is due on year 0 and totals 1.7 M USD. The second is due in year 2 and the remaining 1 M USD are paid by the investor.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
# Total Plants	0	0	1	2	4	6	7	7
IP Valorization	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
CAPEX	\$ (1 700 000)	\$ -	\$ (1 000 000)	\$ -	\$ -	\$ -	\$ -	\$ -
Royalties IP (1%)	\$ -	\$ -	\$ (47 559)	\$ (166 457)	\$ (372 547)	\$ (649 976)	\$ (967 037)	\$ (1 188 980)
Royalties Plant (4%)	\$ -	\$ -	\$ 190 237	\$ 665 829	\$ 1 490 188	\$ 2 599 903	\$ 3 868 149	\$ 4 755 921
FCF INVESTOR	\$ (1 700 000)	\$ -	\$ (857 322)	\$ 499 372	\$ 1 117 641	\$ 1 949 927	\$ 2 901 112	\$ 3 566 941

Table 11 – Investment Structure

In this scenario, for the investor in this technology, the Net Present Value (NPV) is 4.3 M USD, with an IRR of 31%. The payback period is 5 years. This opportunity can be better leveraged in scenario 1 if the investor is also the Plant Developer. Also, the funds and incentives to be available by the European Union can provide additional sources of value to the opportunity presented.

Investor NPV	\$ 4 479 881
Payback	5
IRR	32%

Table 12 – Investor DCF

5. Net Environmental Impact

5.1. Calculation of the Environmental Impact of Plastic

When calculating the annual Net Environmental Impact of this technology and for each production plant, both 1. Amount of greenhouse gas prevented by removing waste plastic from the environment and preventing them to be incinerated, and 2. the wax production impact, were considered.

To calculate the equivalent CO₂ gas emissions for the 18 000 tons of plastic per year for each plant, it is necessary to access the amount of tons emitted per one ton of plastic, and the proportion of which is related to plastic waste. To identify the environmental impact of removing the amount of waste plastic needed, it was accessed the equivalent greenhouse gas emissions of the same amount of plastic if it was dumped in landfills or incinerated.

When all the plastic life cycle is considered, the emissions from plastics in 2015 were equivalent to nearly 1.8 billion metric tons of CO₂ (University of California - Santa Barbara, 2019). Having in consideration the +14,3% growth in plastic production from 2015 to 2019 (Graph 1.1.), and overall demand stated in previous chapters, nowadays the value for volume of CO₂ emitted must reach 2.06 billion metric tons.

Proportionally, it was calculated that one ton of plastic is equivalent to 5,59 metric tons of CO₂ emission, which means that 18 000 tons of plastic per year – the amount needed as feedstock for one production plant, is equivalent to 100 620 metric tons of CO₂ emissions per year. This amount represents the whole production and transformation process and plastic life cycle. To account only for the emissions made after the feedstock becomes waste, it was estimated that 9% of the total plastic greenhouse gas emissions comes from current waste management options such as landfill burns (Nature Climate Change, 2019).

That way, the amount of greenhouse gas prevented yearly by removing 18 000 tons of waste plastic from the environment is 9 056 metric tons of CO₂ emissions per year. This value corresponds to the creation of a positive footprint using this Plastic to Wax Technology.

5.2. Calculation of the Environmental Impact of Wax

When determining the wax production's impact in terms of CO₂ emissions, the 2018 guidelines for greenhouse gas emission measurement from Natural Environment Agency were used (National Environment Agency, 2018). Under lubricants and paraffin waxes, the agency uses the following formula:

$$E_{CO_2} = Q_f \times NCV_f \times C_f \times O_f \times \frac{44}{12}$$

Q_f = Quantity of lubricant or paraffin wax (f). The output of each production plant is 12 000 tons of wax.

NCV_f = Net calorific value of lubricant or paraffin wax (f) used. This value is constant and equal to 0,0399.

C_f = Carbon content of lubricant or paraffin wax (f). This value is reported, and according to the named report, equal to 20.

O_f = Fraction of the lubricant or paraffin wax (f) oxidized during use. This value is reported, and according to the named report, equal to 0,2.

44/12 = Formula Coefficient reported for lubricants and paraffin waxes.

Given the reported numbers stated above, the amount of CO₂ emissions, equivalent to the production of 12 000 tons of wax totals to 7 022,4 metric tons of CO₂.

The formula used for the calculation of the environmental impact of the production of wax is not intended for this specific technology production process. However, the production cycle, processes and products used are similar to the common wax production. Thus, the environmental impact calculated will not diverge by a significant volume the 7 002,4 metric tons of CO₂ emissions.

5.3. Calculation of the Net Environmental Impact

With both calculations developed, it is possible to state that the yearly net environmental impact of the project is positive, and equal to 2 033,6 metric tons of CO₂ per year and per plant developed. This value does not account for transportation and logistics environmental impact and CO₂ emissions.

If we consider a 10-year production plant, and the assumed 7 production plants that would be developed, this results in a total positive environmental impact of 142 352 metric tons of CO₂.

The net impact can also be calculated in terms of carbon credits. A carbon credit is a permit that allows a particular company to emit a certain volume of CO₂ or other greenhouse gases. One carbon credit is equivalent to one metric ton of CO₂. These credits can be sold to other entities that need to pollute more than the number of credits that they have.

So, the calculated net environmental impact of 142 352 metric tons of CO₂ for the duration of the project, is equivalent to 142 352 carbon emission credits.

According to IHS Markit's Global Carbon Index, the current weighted global price on carbon is equivalent to 20.81 USD per ton (Carbon Credit Capital, 2020). This value can vary depending on the quality and economic value of the carbon credit, but for the purpose of this calculation, the average price of 20.81 USD per ton was used. For this technology, this results in 2 962 thousand USD, to monetize on the positive environmental impact.

This poses as an advantage of this technology and an additional way to increase revenue, monetizing on these credits, selling them to other companies. Also, purchasing carbon credits also has a positive impact to the environment, since it contributes to a transition to low-carbon emission planet.

6. Conclusions and Limitations

The focus of this dissertation is to test the viability of a technology that tackles the present environmental issues related to waste plastic and its expected growth for the following years. As plastic production and consumption continues to increase, with an expected CAGR for the next years (2021-2028) of around 3,4%, it becomes imperative to find alternative and innovative solutions for waste plastic.

Additionally, European countries have been expecting bans to the export of their waste plastic to other countries. This causes an alarming problem since these western countries are suddenly confronted with vast amounts of waste with no management strategies or alternative solutions to deal with them.

In this context, the technology presented comes as an attractive business opportunity within the scope of Impact Investing. Also leveraging from the recycle and environmental European targets to 2030, that come with several funds directed to related environmental issues, a financial return for the investor is also expected. The business plan developed shows a positive return of investment in a commercial scale industrial facility using this technology, with a NPV of 4.3 M USD (for the case study of Portugal) and an IRR of 28%. This IRR can range between 26% and 31%, depending on the countries selected for the production plants.

In the case of a potential investor for the financing of a pilot scale facility to prove the technology, we calculate a Discounted Cash Flow model, considering that the potential investor was not the plant developer. If this is the case, the investor will receive a yearly sales-based royalty of 4%, for each commercial plant developed. The intellectual property is on the process of being approved, and as of that data it is available for 7 years. During this time, the investor is obligated to pay a 1% royalty regarding the use of this technology. With an initial investment of 2.7 USD, the Net Present Value (NPV) is 4.3 M USD, if we consider the development of 7 commercial plants. The Investment Return Rate (IRR) with all the assumptions taken is 31%. For this project, the projected payback period is 5 years.

Considering the need of a positive impact channeled from this technology, the impact on the environment was also calculated and accounted for. Deriving from both the impact of plastic and its prevention to be dumped or incinerated, and the production of the wax, a net environmental impact of 2 033,6 metric tons of CO₂ per year and per plant developed was estimated. When the assumptions made for the business plant regarding the number of plants

and the years of production, a total of 142 352 metric tons of CO₂ are prevented to be emitted to the environment, causing a positive impact.

Regarding limitations, for the model presented, plastic availability should be considered, depending on the structure of waste management of each one of the selected countries.

The steadiness of the waste plastic inflows to the production plants should be taken into consideration, since depending on each country recycling structure and volume of waste plastic, it can be impossible to get the 18 000 tons of waste plastic needed per year. If this is the case, the plant would not run at 100% capacity, what would decrease the financial return of the investor. Smaller plants, with smaller facilities and capacity can also be studied, to accommodate for reduced quantities of feedstock.

Also, the values of plastic production and recycling rates per country, since they come from desk research work, may have a margin of error. Some countries don't have a structured and formal information about the quantity of plastic managed and recycled. That way, the values are more of a guidance for the dimension of the country and the possible number of plants that could be developed.

Having these premises in consideration both the analysis and the limitations of the study, the suggested sequence of countries for the development of the commercial plants is as follows: Switzerland, Germany, and Portugal. The first two countries were selected based on financial return on investment, 31% and 28% respectively. Portugal was selected due to national market knowledge. During the research process for the development of this dissertation, the interviews made to market specialist prove that Portugal would be a feasible target for this technology, even if at a smaller scale (due to its volume of plastic production, only has capacity for one production plant).

7. Reverences

- Grand View Research Study, April 2021
- Plastics Europe, Plastics – The Facts Report, 2019
- Plastics Europe: Belgium, 2020
- da Costa, J.P., et al., (Nano) plastics in the environment–sources, fates and effects. Science of the Total Environment, 2016
- Jambeck, J.R., et al., Plastic waste inputs from land into the ocean. Science, 2015
- European Parliament Study, The environmental impacts of plastics and micro-plastics use, waste and pollution: EU and national measures, Oct 2020)
- European Commission, Plastic Waste: a European strategy to protect the planet, defend our citizens and empower our industries, 2018
- Plastic & Climate: The Hidden Costs of a Plastic Planet, CIEL
- Nature Climate Change volume 9, (2019), Strategies to reduce the global carbon footprint of plastics
- University of California - Santa Barbara. (2019, April 15). Plastic's carbon footprint: Researchers conduct first global assessment of the life cycle greenhouse gas emissions from plastics. ScienceDaily. Retrieved May 26, 2021
- Carbon Credit Capital, 2020

8. Annexes

Table 3 – Portugal Plastic Production Forecast 10 years

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Annual Waste Plastic Production (tons)	600 000	612 000	624 240	636 725	649 459	662 448	675 697	689 211	702 996	717 056	731 397
Annual Recycled Rate (%)	12,0%	12,1%	12,2%	12,4%	12,5%	12,6%	12,7%	12,9%	13,0%	13,1%	13,3%
Annual Plastic Collected	72 000	74 174	76 414	78 722	81 100	83 549	86 072	88 671	91 349	94 108	96 950
European Plastic Demand per Type (%)											
PP Plastic	13 896	14 316	14 748	15 193	15 652	16 125	16 612	17 114	17 630	18 163	18 711
HDPE Plastic	8 784	9 049	9 323	9 604	9 894	10 193	10 501	10 818	11 145	11 481	11 828
LDPE Plastic	12 600	12 981	13 373	13 776	14 192	14 621	15 063	15 517	15 986	16 469	16 966
PET	5 544	5 711	5 884	6 062	6 245	6 433	6 628	6 828	7 034	7 246	7 465
Others	31 176	32 118	33 087	34 087	35 116	36 177	37 269	38 395	39 554	40 749	41 979
Country's Total Plant Capacity											
PE (85%)	21 384	22 030	22 695	23 380	24 087	24 814	25 563	26 335	27 131	27 950	28 794
PP (10%)	2 516	2 592	2 670	2 751	2 834	2 919	3 007	3 098	3 192	3 288	3 388
PET (2,5%)	629	648	668	688	708	730	752	775	798	822	847
Others (2,5%)	629	648	668	688	708	730	752	775	798	822	847
Total Mixed Waste Plastic	25 158	25 917	26 700	27 506	28 337	29 193	30 075	30 983	31 918	32 882	33 875
# Possible Plants in Portugal	1,40	1,44	1,48	1,53	1,57	1,62	1,67	1,72	1,77	1,83	1,88

Table 4 - Business Plan for 1 production plant in Portugal

	Year 0	Year 1	Year 2	Year 3	Maturity Year						
					Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
# Plants	0	0	1	1	1	1	1	1	1	1	1
Production Capacity	0	0	30,0%	75,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
% Country Plastic needed for this technology		0,0%	20,2%	49,1%	63,5%	61,7%	59,9%	58,1%	56,4%	54,7%	53,1%

Table 7 - Business Plan for 1 production plant in Portugal

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
# Plants	0	0	1	1	1	1	1	1	1	1	1
Production Capacity	0	0	30,0%	75,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
% Country Plastic needed for this technology		0,0%	20,2%	49,1%	63,5%	61,7%	59,9%	58,1%	56,4%	54,7%	53,1%
Distribution (%)	30%	60%	5%	5%							
BP - 1 Plant	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
CAPEX	\$ (7 882 692)	\$(15 765 383)	\$ (1 313 782)	\$ (1 313 782)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Waxes		\$ -	\$ 4 213 350	\$ 10 533 375	\$ 14 044 500	\$ 14 044 500	\$ 14 044 500	\$ 14 044 500	\$ 14 044 500	\$ 14 044 500	\$ 14 044 500
Liquids (naphtha, distillate)		\$ -	\$ 542 571	\$ 1 356 427	\$ 1 808 569	\$ 1 808 569	\$ 1 808 569	\$ 1 808 569	\$ 1 808 569	\$ 1 808 569	\$ 1 808 569
Total Revenues		\$ -	\$ 4 755 921	\$ 11 889 802	\$ 15 853 069	\$ 15 853 069	\$ 15 853 069	\$ 15 853 069	\$ 15 853 069	\$ 15 853 069	\$ 15 853 069
Fixed Costs		\$ -	\$ (575 592)	\$ (575 592)	\$ (904 038)	\$ (1 232 483)	\$ (1 232 483)	\$ (1 232 483)	\$ (1 232 483)	\$ (1 232 483)	\$ (1 232 483)
Labour Costs		\$ -	\$ (523 200)	\$ (1 046 400)	\$ (1 046 400)	\$ (1 046 400)	\$ (1 046 400)	\$ (1 046 400)	\$ (1 046 400)	\$ (1 046 400)	\$ (1 046 400)
Variable Costs		\$ -	\$ (993 657)	\$ (2 484 143)	\$ (3 312 191)	\$ (3 312 191)	\$ (3 312 191)	\$ (3 312 191)	\$ (3 312 191)	\$ (3 312 191)	\$ (3 312 191)
Plant Royalties 3%		\$ -	\$ (142 678)	\$ (356 694)	\$ (475 592)	\$ (475 592)	\$ (475 592)	\$ (475 592)	\$ (475 592)	\$ (475 592)	\$ (475 592)
Total Operating Expenses		\$ -	\$ (2 235 127)	\$ (4 462 829)	\$ (5 738 220)	\$ (6 066 666)	\$ (6 066 666)	\$ (6 066 666)	\$ (6 066 666)	\$ (6 066 666)	\$ (6 066 666)
EBITDA		\$ -	\$ 2 520 794	\$ 7 426 973	\$ 10 114 849	\$ 9 786 403	\$ 9 786 403	\$ 9 786 403	\$ 9 786 403	\$ 9 786 403	\$ 9 786 403
Taxes (22,5%)		\$ -	\$ (744 539)	\$ (1 848 429)	\$ (2 453 202)	\$ (2 379 301)	\$ (2 379 301)	\$ (2 379 301)	\$ (2 379 301)	\$ (2 379 301)	\$ (2 379 301)
Cash Flow	\$ (7 882 692)	\$(15 765 383)	\$ 462 473	\$ 4 264 761	\$ 7 661 647	\$ 7 407 102	\$ 7 407 102	\$ 7 407 102	\$ 7 407 102	\$ 7 407 102	\$ 7 407 102

Table 10 – DCF Comparison between selected countries

	Portugal	Spain	UK	Sweden	Austria	Switzerland	Belgium
% Country Plastic needed for this technology	63,5%	13,9%	4,4%	7,4%	9,2%	8,5%	22,1%
BP - 1 Plant	Year 4	Year 4	Year 4	Year 4	Year 4	Year 4	Year 4
Waxes	\$ 14 044 500	\$ 14 044 500	\$ 14 044 500	\$ 14 044 500	\$ 14 044 500	\$ 14 044 500	\$ 14 044 500
Liquids (naphtha, distillate)	\$ 1 808 569	\$ 1 808 569	\$ 1 808 569	\$ 1 808 569	\$ 1 808 569	\$ 1 808 569	\$ 1 808 569
Total Revenues	\$ 15 853 069	\$ 15 853 069	\$ 15 853 069	\$ 15 853 069	\$ 15 853 069	\$ 15 853 069	\$ 15 853 069
Fixed Costs	\$ (904 038)	\$ (904 038)	\$ (904 038)	\$ (904 038)	\$ (904 038)	\$ (904 038)	\$ (904 038)
Labour Costs	\$ (1 046 400)	\$ (1 308 000)	\$ (2 616 000)	\$ (2 616 000)	\$ (2 616 000)	\$ (2 616 000)	\$ (2 616 000)
Variable Costs	\$ (3 312 191)	\$ (3 312 191)	\$ (3 312 191)	\$ (3 312 191)	\$ (3 312 191)	\$ (3 312 191)	\$ (3 312 191)
Plant Royalties (3%)	\$ (475 592)	\$ (475 592)	\$ (475 592)	\$ (475 592)	\$ (475 592)	\$ (475 592)	\$ (475 592)
Total Operating Expenses	\$ (5 738 220)	\$ (5 999 820)	\$ (7 307 820)	\$ (7 307 820)	\$ (7 307 820)	\$ (7 307 820)	\$ (7 307 820)
EBITDA	\$ 10 114 849	\$ 9 853 249	\$ 8 545 249	\$ 8 545 249	\$ 8 545 249	\$ 8 545 249	\$ 8 545 249
Tax	\$ (2 453 202)	\$ (2 234 719)	\$ (1 866 704)	\$ (2 333 379)	\$ (1 866 704)	\$ (718 681)	\$ (1 960 039)
EBITDA - Taxes	\$ 7 661 647	\$ 7 618 530	\$ 6 678 545	\$ 6 211 869	\$ 6 678 545	\$ 7 826 568	\$ 6 585 210
WACC	8,9%	8,0%	5,9%	5,5%	6,1%	5,5%	6,4%
DCF 10y	10 226 053 €	11 526 516 €	10 242 670 €	8 619 807 €	9 812 532 €	16 742 724 €	8 782 198 €
DCF Perpetuity	30 030 856 €	36 885 653 €	55 131 346 €	57 193 780 €	51 674 401 €	72 129 725 €	46 622 719 €
DCF	40 256 909 €	48 412 169 €	65 374 016 €	65 813 587 €	61 486 933 €	88 872 450 €	55 404 917 €
IRR 10Y	27%	27%	26%	25%	26%	29%	25%