

# **Economic and financial analysis of a green poly(vinyl chloride) investment project**

**Leonardo Corrêa Gomes**

*Final dissertation submitted to Escola Superior de Tecnologia e Gestão of Instituto Politécnico de Bragança to obtain the master's degree in Chemical Engineering in the ambit of the double diploma with Universidade Tecnológica Federal do Paraná.*

Supervisor:

**PhD Prof. António José Gonçalves Fernandes**

Co-supervisor:

**Dra. Prof. Giane Gonçalves Lenzi**

**Bragança**

**2021**

## **DEDICATION**

*I dedicate this work to all the people who  
somehow helped me to be  
the person I am today.*

## **ACKNOWLEDGEMENTS**

To PhD. Prof. José Gonçalves Fernandes and Dra. Prof. Giane Gonçalves Lenzi, for the guidance, support and help that were essential for the development of this work.

To Dra. Prof. Juliana Martins Teixeira de Abreu Pietrobelli, for all the help on the journey from Brazil to Portugal.

To all my friends for welcoming me and being with me all time.

The dual diploma agreement between Universidade Tecnológica Federal do Paraná and Instituto Politécnico de Bragança.

To Universidade Tecnológica Federal do Paraná and Instituto Politécnico de Bragança.

## **ABSTRACT**

Poly (vinyl chloride), PVC, is the second most consumed thermoplastic in the world with great potential for industrial growth due to its great demand, versatility and employability. The literature points out that 80% of the PVC produced used the polymerization technique by suspension of the vinyl chloride monomer, the main raw material of the process. This process has 85 to 95% conversion, and the remaining percentage, being mostly made up of vinyl chloride monomer (main raw material of the process) must undergo purification processes due to the high hazard it presents to human life. . Therefore, this work will present the construction of a fictitious company called BiPlastic focused on the production of PVC together with a method of recycling and purifying the monomer in the production line itself. Simultaneously, it is intended that the company uses the monomer produced from natural sources, that is, without the use of fossil sources, commonly used by the current polymeric industries. As a result, the company's final product will be green PVC, whose presence is unusual in the current market environment. The objective of the work is to shape a business plan that assesses whether, when building a company with such specifications, there will be profit considering the current moment in the Portuguese and worldwide market. For this, from the literature and data provided by the main polymeric companies in the market, an annual production of 800,000 kg of the product was proposed and that, based on this data, all the necessary infrastructure for construction would be fitted of the company that it supported, including raw materials, labor and sales and marketing plan and all its financial plan, and the cost calculations involved in all stages were determined from literature and market data current. When carrying out the financial analysis and projections, it was possible to determine that, based on the calculated data and assumptions implemented during the work, that the company set up with such specifications is viable, presenting profit from its 6th year with possibilities to invest in new phases and guidelines to expand Biplastic and its production process.

**Keywords:** Vinyl chloride monomer; green entrepreneurship; polymeric process.

## INDEX OF TABLES

Table 1. Standard procedure for polymerization of PVC in suspension.....	42
Table 2. VCM emission limit.....	46
Table 3. BiPlastic's green polymer production ratio .....	52
Table 4. List of raw materials required for BiPlastic's annual production.....	53
Table 5. Conditions of the PVC production process by BiPlastic .....	54
Table 6. General mass balance for production of 8 poly (vinyl chloride) .....	56
Table 7. Reactor sizing for polymerization.....	56
Table 8. Sizing the suspension tank .....	57
Table 9. Mass Balance Stripper.....	59
Table 10. Stripper sizing .....	60
Table 11. Mass balance for centrifuge .....	63
Table 12. Centrifugal technical sheet.....	63
Table 13. Mass Balance Dryer .....	64
Table 14. Sieve mass balance.....	66
Table 15. Mass balance for reactor pairs $R_1$ e $R_1'$ .....	67
Table 16. Daily mass balance of production.....	67
Table 17. BiPlastic equipment and cost benchmark. ....	83
Table 18. Estimation of costs of BiPlastic raw materials.....	84
Table 19. General utilities price, in dollars. ....	85
Table 20. Lang's factor.....	87
Table 21. Value reference per equipment. ....	87
Table 22. Result of investment costs of fixed and total capital in dollars.....	88
Table 23. Main inputs and suppliers for the BiPlastic process. ....	91
Table 24. BiPlastic cost estimation. ....	101

Table 25. BiPlastic cash flow.....	103
Table 26. Cash flow with new loan.....	104
Table 27. NPV values at 10 and 5%.....	107
Table 28. Criteria for the analysis of NPV and IRR. ....	108
Table 29. Result IRR and VPL BiPlastic. ....	108
Table 30. BiPlastic sales projections.....	111
Table 31. financial analysis of BiPlastic projections. ....	112
Table 32. Projection for 12 years of payments of medium- and long-term debts.....	113

## INDEX OF FIGURES

Figure 1. Innovation of polymers of fossil origin in relation to time.....	14
Figure 2. Linear, branched, and crosslinked structure, consecutively. ....	16
Figure 3. Geographical distribution of PVC consumption in 2012.....	22
Figure 4. Percentage of the distribution of PVC demand in 2017. ....	23
Figure 5. Main applications of PVC in 2017. ....	24
Figure 6. Polymer demand in the European Union (EU-28) between 2016 to 2019. ....	25
Figure 7. Generic reaction of transformation of the vinyl chloride monomer into poly (vinyl chloride). ....	26
Figure 8. PVC consumption in relation to different industry sectors.....	27
Figure 9. Productive line derived from fossil sources.....	29
Figure 10. Petrochemical chain of ethylene. ....	30
Figure 11. Variation of ethylene prices from 2000 to 2018. ....	31
Figure 12. Relationship between quantity of raw materials used vs. ethylene produced. ....	32
Figure 13. Productive process of ethanol dehydration.....	33
Figure 14. Cost of ethanol production from different biomasses.....	35
Figure 15. Price prediction of green ethanol and its raw materials.....	36
Figure 16. Monomer production process by the chlorine / ethylene reaction.....	39
Figure 17. General PVC production.....	40
Figure 18. General reaction of polymerization of the monomer in PVC.....	40
Figure 19. Flowchart of the PVC production process in suspension. ....	43
Figure 20. Scheme of the suspension polymerization reactor.....	44
Figure 21. Evolution of pressure and internal temperature of the reactor and jacket temperature during polymerization. ....	45

Figure 22. VCM recovery in the PVC production process via suspension polymerization.....	47
Figure 23. Simplified production process of poly (chloride) of vinyl by suspension.....	50
Figure 24. BiPlastic production process block diagram.....	51
Figure 25. Representation of the polymerization reactor in a block diagram. ....	55
Figure 26. Representation of the suspension tank in block diagram.....	57
Figure 27. Stripper representation. ....	58
Figure 28. Stripper representation by block diagram. ....	59
Figure 29. Representation of the storage tank in block diagram.....	60
Figure 30. Representation of the centrifuge in block diagram. ....	62
Figure 31. Representation of the dryer in block diagram.....	64
Figure 32. Representation of the sieve in block diagram. ....	65
Figure 33. Company logo.....	73
Figure 34. BiPlastic strategic vision.....	75
Figure 35. Top view of BiPlastic's location. ....	77
Figure 36. Location of the Estarreja Chemical Complex with the location of BiPlastic. ....	77
Figure 37. Layout layout of BiPlastic. ....	79
Figure 38. BiPlastic organization chart. ....	80
Figure 39. Porto de Aveiro and pipeline from Porto to the company. ....	92
Figure 40. Global percentage of bioplastic production in 2020 and 2025. ....	93
Figure 41. Price ratio of poly (vinyl chloride) from fossil sources between 2017 to 2021.....	95
Figure 42. BiPlastic seal.....	98
Figure 43. Trend graph of accumulated cash flow from Table 25 and 26, respectively.....	105
Figure 44. BiPlastic accumulated cash flow projection trend graph.....	114

## INDEX

<b>1. INTRODUCTION .....</b>	<b>10</b>
1.1. JUSTIFICATION .....	10
1.2. OBJECTIVE .....	11
1.3. HISTORICAL REVIEW .....	12
<b>2. POLYMERS .....</b>	<b>15</b>
2.1. DEFINITION AND CLASSIFICATION OF POLYMERS .....	15
2.1.1. <i>Basic concepts of the polymeric molecule</i> .....	17
2.2. BIOPOLYMERS AND GREEN POLYMERS .....	19
<b>3. POLY(VINYL CHLORIDE ) - PVC .....</b>	<b>21</b>
3.1. WORLD CONTEXT AND DEMAND .....	21
3.2. DEFINITION AND PROPERTIES .....	25
3.3. DESCRIPTION OF THE PVC PRODUCTION PROCESS .....	27
3.3.1. <i>Raw material</i> .....	27
3.3.2. <i>Production - vinyl chloride monomer</i> .....	36
3.3.3. <i>Polymerization synthesis of Poly(vinyl chloride) - PVC</i> .....	39
<b>4. FICTIONAL COMPANY: BIPLASTIC .....</b>	<b>49</b>
4.1. PRODUCTIVE PROCESS .....	49
4.1.1. <i>Definition of productive capacity</i> .....	51
4.1.2. <i>Calculation Report</i> .....	53
4.1.3. <i>Preliminary treatment of effluents</i> .....	68
<b>5. BUSINESS PLAN .....</b>	<b>70</b>
5.1. METHODOLOGICAL ASPECTS .....	70
5.2. EXECUTIVE SUMMARY .....	72
5.2.1. <i>History of ideas and / or promoters</i> .....	74
5.2.2. <i>Strategic vision and business mission</i> .....	75
5.3. OPERATIONAL PLAN .....	76
5.3.1. <i>Location</i> .....	76
5.3.2. <i>Installations</i> .....	78
5.3.3. <i>Organization chart and manpower</i> .....	80
5.3.4. <i>Estimation of equipment costs</i> .....	82
5.3.5. <i>Estimation of raw material costs</i> .....	83

5.3.6.	<i>Industrial services/utilities</i>	84
5.3.7.	<i>Estimated investment costs</i>	86
5.3.8.	<i>Critical points</i>	88
5.4.	MARKET ANALYSIS	89
5.4.1.	<i>Underlying Market</i>	89
5.4.2.	<i>Pricing</i>	94
5.5.	MARKETING PLAN	97
5.5.1.	<i>Commercial strategy</i>	98
5.5.2.	<i>Environmental certifications</i>	99
5.5.3.	<i>New consumption pattern</i>	99
5.6.	FINANCIAL EVALUATION	101
5.6.1.	<i>Cash flow</i>	101
5.6.2.	<i>Net Present Value (NPV) and Internal Rate of Return (IRR)</i>	106
5.7.	STRATEGIC EVALUATION	108
5.7.1.	<i>Economic scenarios</i>	110
5.7.2.	<i>Financial support</i>	114
<b>6.</b>	<b>CONCLUSION AND FUTURE WORK</b>	<b>116</b>
<b>7.</b>	<b>REFERENCES</b>	<b>118</b>

# **1. Introduction**

The introduction of this work will consist of the presentation of three main points, these being its justification, the presentation of general and specific objectives and the historical review in which it fits.

## **1.1. Justification**

It can be attributed to several sectors due to its great versatility and worldwide demand, poly(vinyl chloride) - PVC - is the second most used thermoplastic in the world. Due to its high consumption and production volume, as well as the high number of researches with the objective of improving its process and product quality, the technologies that surround it have had a notable growth since its emergence until the present day (Peters, Timmerhaus & West, 2003).

Regarding its composition, as pointed out by Rodolfo Jr., Nunes and Ormanji (2006), the material is usually composed of 57% chlorine and 43% ethylene, which are mostly from sea salt inputs and non-renewable sources such as oil and natural gas, respectively.

However, the constant search for new alternatives, driven by technological advances in the sector, lower costs in relation to the production process, in addition to the search for a more sustainable process, led to investment in research with a focus, among others, on the exploration of different sources of raw materials for the production of polymers (Faria, Siqueira, Cristino & Rochar, 2016).

Associating such concerns with the constant oscillation in the price of oil, the concern with the levels of environmental pollution throughout the production cycle and in the environmental wear and tear due to the use of non-renewable raw materials, biopolymers and green polymers have become an attractive industry and consumers of the product. Therefore, when replacing the sources of fossil raw materials with renewable sources, that is, the substitution of petroleum compounds by the use of natural sources, which with chemical treatment will have the same properties as, for example, sugarcane to obtain ethanol, which in turn is treated to obtain ethylene,

makes the process less environmental impact and focused on sustainability (Borschiver, Suzana, Almeida, Luiz, Roitman & Tamar, 2008).

Regarding the production of poly (vinyl chloride), about 80% of its world production is carried out from the suspension polymerization of the vinyl chloride monomer. Its high utilization rate is mainly due to the high conversion rate resulting from the process, which varies between 85 to 95% (Wieme, De Roo, Marin & Heyderickx, 2007).

After the end of production, it is necessary and recommended that the product be treated within the same process, so that the remaining monomer contents no material is retained due to its aggressiveness to the human being (carcinogen) as to its possible reuse / recycling without process (Silva & Góis, 2013).

Therefore, the need to recover the non-converted monomer in production proved to be essential when relating the section to sustainability, reuse of waste and the health of workers and consumers.

## **1.2. Objective**

The following work has as main objective the construction of a business plan for a fictitious company called BiPlastic that will act in the field of polymers having as a final product the green poly (vinyl chloride) together with the recovery of the residual vinyl chloride monomer of the process, assessing whether, within this context, such a business model is economically and financially viable.

Therefore, the specific objectives of this work are:

- Construction of the green poly (vinyl chloride) polymer production line that will be used for the company;
- Construction of a business plan that will address the main aspects for the beginning of the company's activity;
- Analyze and evaluate the economic feasibility of building the company for the production of green poly (vinyl chloride) in the current Portuguese market.

### **1.3. Historical review**

With great applicability and one of the pillars of modern life that revolutionized and gave basis to the technological development of this century, the emergence of the term polymer, from a scientific point of view, occurred in the second half of the last century, being created by the German chemist J. Berzelius, in 1832 (Hage Jr., 1998).

Research and conducting an investigative experiment with natural polymers such as rubber, starch, cellulose and protein played a fundamental role in the development of synthetic polymers, which are the basis for understanding and creating the model that would be replicated in the future by industries. The mastery of the natural rubber vulcanization technique, for example, made it possible for new products, which depended on the elastic factors provided thanks to the technique, to be developed. Hage Jr. (1998) measures that, from 25 tons produced in 1830, the new production with the use of the technique increased to 6,000 tons in 1860. In 1868, with the development of studies by John Wesley Hyatt about the synthesis of cellulose nitrate, new possibilities with natural polymers began to be envisioned. According to Peters et al. (2003), the discovery of adding new products during the production of the synthesis described above, brought further expansion to the area with new possibilities of use and form of application. In 1909, Leo Hendrick Baekeland produced the first synthetic polymer, producing what would later be known as formaldehyde phenol plastic.

However, even at this time, research aimed at understanding both the composition and its molecule were extremely precarious, with no understanding of the macromolecular structure of polymers. In 1920, Professor Hermann Staudinger, an organic chemist at the Federal Institute of Technology (ETH) in Zurich, dedicated himself to studying such polymeric chains, being later recognized in 1953, winning the Nobel Prize in chemistry thanks to his contributions to the field (Hage Jr., 1998; Peters et al., 2003).

With the development and greater knowledge of the transformation process of both natural polymers and the production of synthetic polymers, in 1920, the production of poly(vinyl chloride) - PVC -, nylon and urea formaldehyde began. In the following years, large investments were made in the area, due to the increase in oil exploration, in addition to the need generated by both industrial revolutions and the 1st and 2nd world wars (Ebewele, 2000).

Polymer science has continued to develop over the years, with both industry and academia investing time and money in order to find new materials that could behave with greater versatility but with lower costs and with unique characteristics in relation to already existing materials. In 1950, Karl Ziegler and Giulio Natta discovered catalysts that, when applied in the synthesis of polymers, increased the speed of their production and, consequently, the volume produced, making this discovery extremely important for the expansion of the polymeric industry and its expansion to commercial use (Peters et al., 2003).

In this context, between 1960 and 1970, new discoveries such as polymers resistant to high temperatures caused the use of the material to expand even more to all sectors of the industries and, consequently, to their public. Companies of great renown and reach, such as Coca-cola, began to make use of the material on a large scale by interacting their products already commercialized with plastics, causing, in 1973, the production of plastic to exceed, in relation to the volume produced, the steel industry (Gorgi, 2003; Peters et al., 2003).

Currently, most synthetic polymers are formed from the extraction of monomers in raw natural raw material, such as animal or vegetable carbohydrates and oil, the latter being the most usual by the industry as it is the cheapest to be obtained, in terms of process cost and in relation to the quantity and income generated (Askeland, 2008).

However, it is currently perceived that the use of oil as a raw material has become a critical element mainly due to the constant variation of its commercial cost and the emergence of a new type of consumption mentality, directly related to preservation values with the environment and the origin of the material consumed by them (Askeland, 2008).

Therefore, when these points are associated with the constant search and incentive on the part of the industries for new technologies, the substitution of the use of oil as raw material has become a point of interest to be invested, however considering that the new possibilities should keep the same quality standard at the lowest possible cost. For this, the need to increase the number of researches to discover new sources of raw materials and ways to improve those already existing for the substitution of oil has become essential. And from this scenario, there is a gradual decrease in the number of studies that relate polymers to oil and, consequently, a decrease in new polymers originating from such source, as shown in Figure 1.

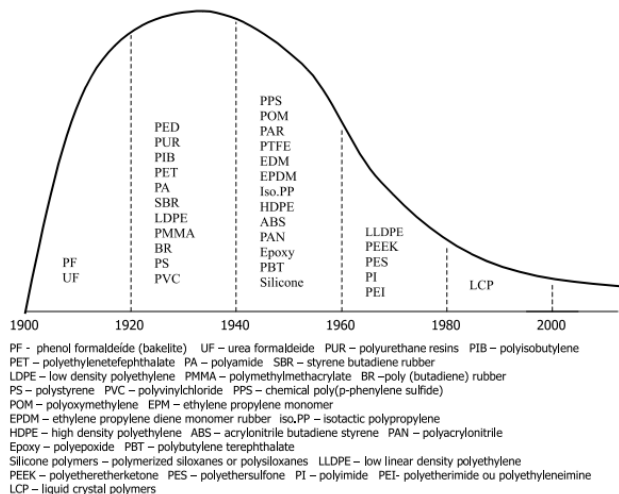


Figure 1. Innovation of polymers of fossil origin in relation to time.

Source: Bastos (2007).

With this, associated with the concern with the residues generated by the polymers and their high degradation time, which can take up to 500 years when not treated beyond the possible accumulations in sanitary landfills, the production and use of biopolymers and green polymers has become a new alternative and solution to such problems (Brito, Agrawal, Araújo & Mélo, 2011; Marinelli, Monteiro, Ambrósio & Branciforti, 2008).

Currently, according to data exposed by PlasticEurope (2020), in 2019, the global production of polymers was approximately 370 million tons, and in Europe alone, the production was approximately 58 million tons, 16% of the world production. year. With a demand of 50.7 million tons in 2019, its main jobs were found in packaging and civil construction, with the construction of plumbing and general utility parts.

According to the Institute for bioplastics and biocomposite (2020), Europe's production capacity, in relation to bioplastic and green plastics, was approximately 2 million tonnes, due to production capacity, to 6 million in 2022. Another data It is pointed out that, in 2019, the European continent presented about 18.4% of the world production of such material. The forecast is that, in 2024, this percentage will rise to 28.1% demonstrating the interest and the increased demand for more sustainable solutions, both by the industry and its consumer public.

## **2. Polymers**

In order to understand and acclimatize to the polymeric branch, it is essential to understand the chemical and physical properties of polymers so that, after a brief description of the main sections that influence the material, it can be funneled towards PVC and, consequently, in the production and construction of the fictitious company. Therefore, this section will present the definition and classification of polymers, their basic concepts necessary for their understanding and a brief presentation of green polymers and their nuances.

### **2.1. Definition and classification of polymers**

Countless researches on natural monomers and polymers were developed from 1830, however, it is only in 1920 that through researches carried out by researcher Hermann Staudinger the term polymer was associated with its chemical part, and it was then discovered that such material is a set of long molecular chains and of high molecular weight and that have difficulties in being isolated (Mano & Mendes, 2004).

With Greek origin, the word polymer is the junction of "poli" which means a lot and "mere" which means repetition unit. Therefore, polymers can be classified as a macromolecule composed of numerous repetition units called mere, being connected to each other by covalent bonds (Chaves, Cardoso & Reis, 2015).

The term plastic was adopted by the industry to refer to the set of all commercially sold polymers, whether they come from artificial or synthetic raw materials. A point to be raised is about the distance that there must be between the term's plastic and polymers, since, all plastics are polymers, but not all polymers are plastic (Peruzzo & Canto, 2006; Vanin, 1994).

The characteristics, such as its structure, bonds and behaviors, in addition to the properties that each polymer presents are mainly determined by the variation that occurs in its structure and that are modified from the production process in which the raw material is subjected (Stevens, 1999).

Regarding their structure, polymers can be classified as linear, branched and crosslinked, and this characteristic affects their level of solubility, stability and rigidity. Figure 2 visually demonstrates the types of structure and how these chains are arranged. It is worth mentioning that, in relation to the figure presented, from right to left, polymers tend to be more stable and rigid, that is, crosslinked structures behave in a more stable way than linear and branched (Peters et al., 2003).



**Figure 2.** Linear, branched, and crosslinked structure, consecutively.

Source: Endo (2002).

Another property and characteristic assumed by the polymers is if they, when heated, soften and can be remodeled or if, despite the heat, they remain rigid without the possibility of remodeling and these are named respectively as thermoplastics and thermosets. Relating this characteristic to the type of bond, the polymers that have a linear or branched structure are classified as thermoplastics, that is, they are materials that under the action of fire are softened and can be remodeled and cooled powders remain in the new designated mold (Chaves et al., 2015).

However, polymers with a crosslinked structure depend exclusively on the degree of cross-linking between their chains. If the degree of bonding is low, the polymer will behave similarly to polymers with a linear or branched structure, with behavior of thermoplastics. But, if the degree of bonding is high, the polymer loses such softening behavior, making it thermoregic (Stevens, 1999).

Although, as already mentioned, the industry adopts the term plastic to refer to all commercially sold polymers, this, too, is a term used for the classification of polymers, which can be classified as plastic, fiber or elastomer. The fibers have strong intermolecular bonds thus decreasing their extensibility, making them more rigid. As for the elastomers, due to their weak intermolecular bonding, they become less rigid and more flexible. Plastics fluctuate between these

two definitions, with other factors, such as production conditions and their chemical process, influencing the final characteristics of the product (Peters et al., 2003).

Still on production, during the polymerization reaction, the process in which the monomers are transformed into polymers, additives and other materials can be added to alter and add different characteristics such as malleability, hardness and resistance to the final product. Polymers are also classified according to their raw material of origin, which can be of fossil, vegetable, etc. and the reactions that originated them, the most common ones in the industry are the ones that use addition reaction, ring opening and the condensation reaction, the latter being more used for the production of PVC due to its high yield and which will be better presented later (Peters et al., 2003).

The understanding of the diverse characteristics that the molecule has demonstrate the great versatility that the product can assume, being, therefore, one of the main factors of the daily and continuous use of polymers in all sectors of human life.

### **2.1.1. Basic concepts of the polymeric molecule**

The polymers present several characteristics being distributed among the physical and chemical ones, being able to be altered according to its geometric, connection and conditions in which it is exposed, as previously mentioned.

In general, the physical characteristics do not involve structural motives, that is, at the molecular level, and may include within it the mechanical, thermal, and electrical properties that the molecule can assume. The mechanical characteristics correspond to the response that such materials showed external mechanical influences, such as deformation or resistance to fracture. Thermal properties refer to the way in which the molecule will behave with the presence, or not, of heat. The electrical properties, on the other hand, concern the characteristics that the molecule can assume when it meets electricity, being able to assume characteristics of conductors or non-conductors, for example (Mano, 2019).

The chemical characteristics are directly linked to the process that the polymer will undergo. Different conditions and products in which the material is exposed will alter or give it some specific characteristics that will be important for the final role that it will play. Therefore,

such characteristics are previously studied and dated to determine exactly what to do to give the final material a certain characteristic (Mano, 2019).

Regarding the production of polymers, tapering for the production of poly (chloride) vinyl, the terms monomers, polymerization, homopolymerization and copolymers are important concepts for understanding the entire process, which are presented below.

Monomer is the raw material for the formation of the polymer. It can be produced from three main routes that refer to the base compound for its production, which are the route from ethane, from acetylene and from ethylene / chlorine. The monomer is a simple molecule that, depending on the conditions in which it is subjected and because it makes two different connections due to its terminations, gives rise to numerous repetition units, called mere, which in turn form the polymers from the process called polymerization (Rodolfo Jr. et al., 2006).

Polymerization is the set of chemical reactions that take place inside the reactor, carrying out the transformation of the monomer into polymers. Regarding the growth mechanism of the polymeric chain, they can be by polymerization in stages (repeated reactions of condensation in which the elimination of molecules occurs in its process) or by addition (reactions with successive additions of monomers to the radical present in the chain of a polymer). Within addition polymerization, there are four main processes that can be highlighted: mass polymerization, suspension polymerization, emulsion polymerization and solution polymerization (Mejdell, 1999).

Polymers are also classified according to the components that form their macromolecule, and when they are formed by a single type of repetition unit they are called homopolymers and when they are formed by repetitions of two or more mere they are called copolymers (Rodolfo Jr. et al., 2006).

Such concepts provide the basis for understanding the polymer production process. When funneled for the production of poly (vinyl chloride), we have that its polymerization is carried out by suspension, from the vinyl monomer and that the final product can be characterized as either a homopolymer or a copolymer, depending on the characteristics of its production and the additives that complement it. This section will be discussed below in greater detail.

## **2.2. Biopolymers and Green Polymers**

Considering the current scenario with the increasing increase and volatility in the price of oil and, mainly, the concern with the depletion of fossil sources together with the continuous degradation of the environment, the search for renewable sources that can replace its presence in fuels or sources raw material from several chemical processes has become present, necessary and coveted today (Bastos, 2007).

The solution found in relation to the theme cited for polymers is the use and replacement of polymers from fossil sources by polymers with renewable sources. These polymers are called biopolymers or green polymers.

Biopolymers can be produced from renewable raw materials such as ethanol from renewable sources such as corn, sugar cane, cellulose, chitin, etc. or synthesized from bacteria such as butyric acid or valeric acid. They are considered biocompatible and biodegradable, that is, they decompose in a short period of time, in microbiologically active environments, without producing toxic substances. Their mode of production differs from the current usual chemical process, that is, the machinery that currently exists in industries that are used for production from fossil sources could not be used for the production of biopolymers, this being the main difference between them and green polymers (Bastos, 2007; Brito et al., 2011).

Green polymers, according to Brito et al. (2011), is the name of polymers that were formerly synthesized from raw material from fossil sources but with technological advances started to use renewable sources as raw materials. Examples of green polymers are green polyethylene (green PE) and green vinyl poly (chloride) (green PVC).

The first PE and green PVC was produced from sugar cane ethanol, and this technology was developed by the Braskem Technology and Innovation Center, in Brazil. Together, the technology for transforming ethanol from natural sources into ethylene was polished, direct raw material for the production of monomer, making the whole process free from the need to use fossil sources (Rodolfo Jr. et al., 2006).

The production of green polymers, in addition to reducing dependence on fossil sources, is directly linked to the absorption of CO<sub>2</sub> from the atmosphere due to the use and investment in increasing the amount of renewable raw material. Data released by Brito et al. (2011), indicate that

for each ton of green polymer produced, on average, 2.5 tons of CO<sub>2</sub> is removed from the atmosphere.

The final product, after its useful life, can be reused, recycled or sent to energy recycling systems, which, because they have the same characteristics as plastics, can follow the same final path of such product. A key point related to energy recycling systems is the generation of neutral carbon dioxide emissions due to the cycle of sugar cane capture and release when recycling (Brito et al., 2011).

Despite the growing number of publications on new technologies and possibilities for biopolymers and green polymers in industry, this is still blocked due to the conservatism of polymeric companies linked to the great influence that oil and related companies present. However, even so, due to the great benefits brought about by biotechnology, there is an increasing incentive from governments for their research, development, and application as well as the increase in consumer demand for such products (Brito et al., 2011).

A case to be cited is that it has a direct relationship with the company that this work will set up are the incentives given by the European Union, and the support for biopolymers and green polymers has been presented through the main financial instruments to support the activities of research and development, called Framework Programs, which present support systems for the study and its production with financial and technological support (Bastos, 2007).

### **3. Poly(vinyl chloride ) - PVC**

After defining and explaining, in general, the polymers and their main characteristics, it will be presented in this section the poly (vinyl chloride), PVC, which will be the main product of the fictitious company to be created. In this section will be presented the context and the world demand of the product as well as its definition and properties. The entire production process that is currently used in the production of PVC will also be described, indicating the way of obtaining its raw materials, the formation of the monomer used for the process and the polymeric synthesis.

The process described by this section will serve as a basis for the choices and directions that will be taken to assemble the production of the fictional company BiPlastic, as well as all the measures that will be directed towards the construction of its business plan.

#### **3.1. World context and demand**

In 1835, the vinyl chloride monomer was discovered by Justus Von Liebig, being obtained by the chemical reaction between 1,2-dichloroethane with potassium hydroxide, in an alcoholic solution. Although, currently, obtaining the monomer used for the production of poly (vinyl chloride), for the most part, uses petroleum as a raw material, this was the principle for the most refined research that would lead to the process performed in the days to obtain such a product (Nunes, Rodolfo Jr. & Ormanji, 2002).

E. Baumann, in 1872, described what would come to be known as the first polymerization of MVC and synthesis of PVC. His research description was documented as the induced production of MVC using an isomer. However, with the characteristics described by the researcher, it is currently known that the final product formed coincides with the characteristics of the vinyl poly (chloride) (Rodolfo Jr. et al., 2006).

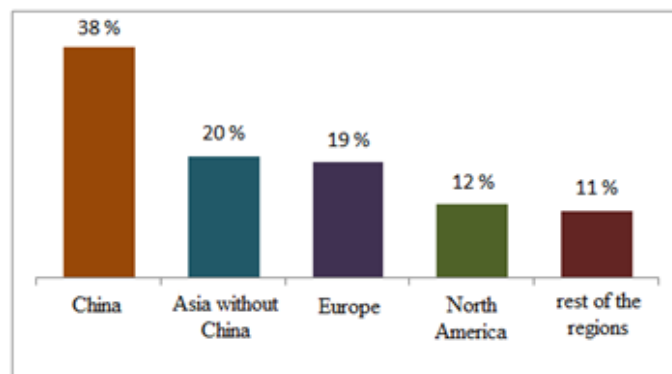
In 1912, through research by the German Fritz Klatte, the process of transforming the monomer into poly (vinyl chloride), using the acetylene route, was developed, this being the beginning for its commercial production, and in 1913 it was PVC patent discovered using this method. In 1920, large-scale production of PVC began in the United States, expanding and thus

gaining the consumer market. Between 1930 and 1940, Germany and the United Kingdom started their production and commercialization of the product (Nass & Heiberger, 1976).

With the implementation and approval of PVC in the consumer market, in 1968 in the United States, the first PVC bottle for consumption of PVC alcoholic beverages was launched on the market. However, through government intervention, it was withdrawn from circulation, which opened the way for other polymers to replace it. However, such an intervention did not occur in Europe, where the circulation of PVC bottles became very popular as containers for wine and water (Gorni, 2003).

In 2005, the worldwide demand for PVC was 35 million tons, rising to 36 million tons in 2006, making it the second most consumed thermoplastic in the world. In 2012, total PVC consumption was approximately 37.4 million tons (Sousa, 2014).

Figure 3 shows the percentage of PVC consumption in 2012 in relation to geographic points with the highest incision of consumption and its production.



**Figure 3.** Geographical distribution of PVC consumption in 2012.

Source: Adapted from Sousa (2014).

From Figure 3, China and the Asian regions consumed around 58% of all world PVC production in 2012. The expansion of the automotive, electrical, and electronic market in China, the first of which is considered the largest world market, contributed for the country to have the highest percentage in relation to the others. Another point to be taken into account is the growing demands for PVC in developing countries (India, China, Indonesia and parts of South America and Africa) due to the high growth that the construction sector thus contributes to the consumption of the product (Gilbert , 2020).

As of 2012, due to the growth and diversification of the use of poly (vinyl chloride) in different sectors of the industry, the growth in relation to the volume of production resulted in greater investments in the area in addition to globalization that brought its consumption worldwide which can be seen from Figure 4.

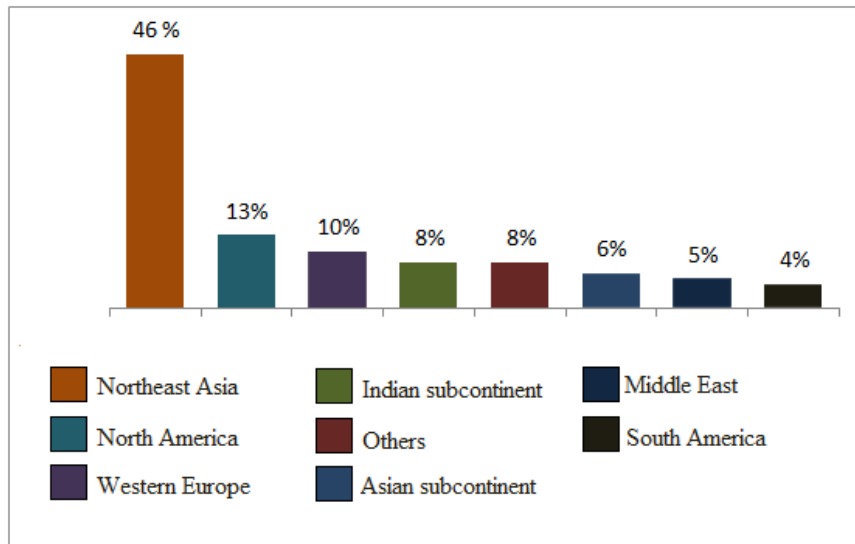


Figure 4. Percentage of the distribution of PVC demand in 2017.

Source: Adapted from Silva (2020).

It is noted evaluating from Figure 3 and Figure 4 that, from 2012 to 2017, there was a relevant difference between the territories with significant percentages in relation to the distribution of PVC demand resulting from the product expansion actions to the world market. According to PlasticEurope (2020), such data remains stable and unchanged in 2019, with Northeast Asia still being the largest producer and exporter of PVC in the world.

Data released in 2018 by Folha de São Paulo indicate that the world production of plastic in 2017 was approximately 348 million tons. In relation to PVC, in 2017 world consumption reached 43.2 million tons, increasing the total consumption by 4% in relation to 2016 (Folha de São Paulo, 2018; Opportimes, 2018).

Figure 5 shows the main applications of PVC in the world in 2017, with globalization and investment in new research both to disseminate it in new sectors and to find new possibilities for the product, from new raw materials for the product to new additives that would give it new characteristics, it brought a greater distribution of territories that produced and consumed PVC.

Forecasts say that with the increase in the possibilities of PVC applications and uses in more sectors of the industry, world demand in 2027 for the material will rise from 2.3 to 3.7% of current consumption (Opportimes, 2018).

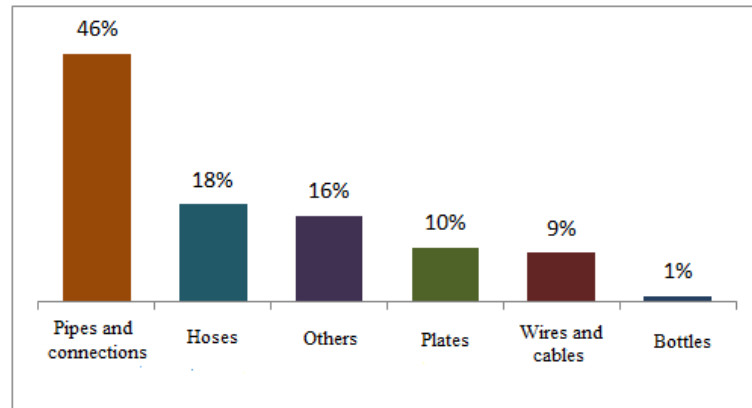


Figure 5. Main applications of PVC in 2017.

Source: Adapted from Silva (2020).

In relation to European consumption, PVC is the 5th most consumed polymer, as shown in Figure 6, highlighting its use in frames, profiles, floor, and wall covering, tubes, cable insulation, garden hoses and inflatable pools. One factor to be considered, demonstrated from 2016 to 2019, is in relation to the constancy in which the percentages of all plastics remained due mainly to the consolidation of the sector in the European continent (PlasticEurope, 2020).

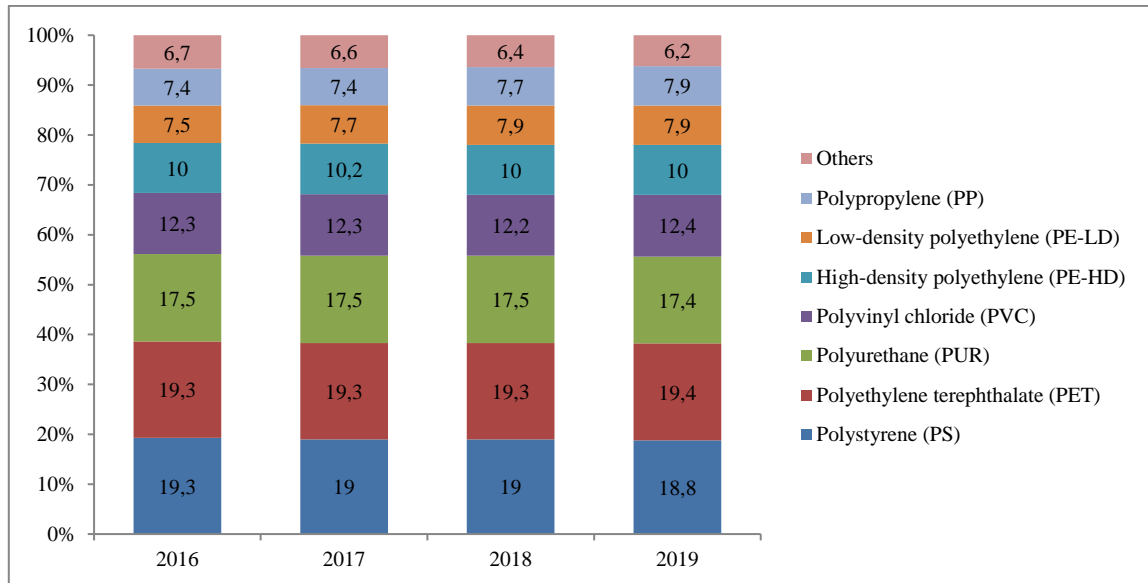


Figure 6. Polymer demand in the European Union (EU-28) between 2016 to 2019.

Source: Adapted from Statista (2021).

According to Marta Drummond, market analyst for thermoplastic resins, the forecast is that, in 2020, the production of PVC and other resins will increase due to the strong growth trend in civil construction, in the automobile and footwear industry, thus showing an optimistic scenario for the area and the product (Chemistry and derivatives, 2019)

### 3.2. Definition and properties

PVC is a thermoplastic polymer that has the vinyl chloride monomer as raw material, with the designation IUPAC (International Union of Pure and Applied Chemistry) 1-chloroethene, also known by the acronym VCM (Vinyl Chloride Monomer) (Hill, 2000).

The vinyl chloride monomer has covalent bonds between its molecules, causing PVC to present characteristics of polymers with linear structures, making them more malleable and easier to adapt. The reaction of transformation of the raw material in the polymer is called polymerization reaction (Hill, 2000).

Figure 7 represents, in a generic way, the reaction of transformation of the monomer into PVC.



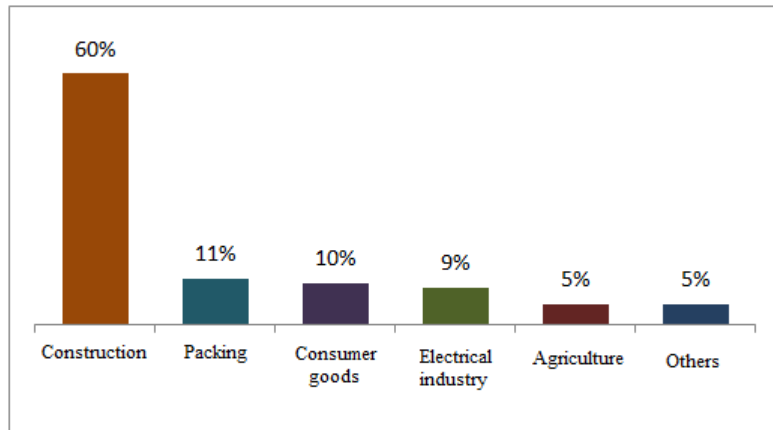


Figure 8. PVC consumption in relation to different industry sectors.

Source: Adapted from Rodrigues (2008).

To make PVC the most versatile and applicable by changing its physical and mechanical characteristics according to the place where it will be used, the production method and the products added, such as thermal stabilizers, lubricants, plasticizers, fillers and others additives are dosed at different stages of production, resulting in such characteristics, as will be explained below (Alsopp, 2003).

### 3.3. Description of the PVC production process

To describe the production process as a whole, it is necessary to address the raw materials that make up the majority of the monomer, which is the main basis for the synthesis of polymerization of PVC. Therefore, in this section will be addressed the ways of obtaining and treating raw materials (both for PVC production of fossil origin and for green PVC), the synthesis of such materials for the production of vinyl chloride monomer as well as their routes and by end the polymerization synthesis for the production of PVC.

#### 3.3.1. Raw material

Being composed of 57% by mass of chlorine, which comes from sea salt and 43% ethylene, which may come mostly from fossil sources or also through processing from natural sources, such

raw materials are directed for the production of vinyl chloride monomer, which in turn, from chemical processes, will be transformed into PVC (Rodolfo Jr. et al., 2006).

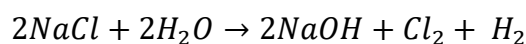
Therefore, the main difference between usual polymers and green polymers is the origin of their raw material. While for polymers from fossil sources (usual), ethylene is obtained from the distillation of petroleum, a non-renewable resource, for green polymers, ethylene is obtained from chemical processes from natural sources that can have different origins, such as sugar cane, corn, potatoes, etc.

Next, the process involving the capture and production of chlorine, ethylene from fossil sources and ethylene from natural sources, raw materials used for the production of PVC, will be described.

### **3.3.1.1. Chlorine**

In general, chlorine is obtained by electrolysis of sodium chloride in an aqueous medium, in a supersaturated solution, where through an electric current, the separation of the components takes place. In the process, chlorine gas is released into the electrolytic cell and by-products (sodium hydroxide and hydrogen gas) are produced at the cathode (Rodolfo Jr. et al., 2006).

Equation 1 represents obtaining the chlorine described.



**Equation 1**

According to Rodolfo Jr. et al. (2006) the world's production at the time were estimated at 37 quadrillion tons per year, with 34% of this amount going to PVC production.

The main processes used to carry out electrolysis within the industry are mercury amalgam, the asbestos diaphragm process, and the membrane process. However, for the PVC production process, the most used is the membrane process, due to the high electrical cost that the mercury amalgam process requires and the high consumption of steam by the diaphragm processes (Rodolfo Jr. et al., 2006).

The membrane process consists of using an organic membrane that physically separates the anode, with chlorine, and the cathode, with the other by-products, not allowing their contact due to a membrane with selective permeability between ions and hydroxyls. This process, as it does not cause potential environmental problems and does not generate waste, becomes highly attractive to industries in addition to being the most financially viable (Rodolfo Jr. et al., 2006).

### 3.3.1.2. Ethene from fossil sources

Ethene is obtained from the cracking / thermal separation of naphtha, through processes in the petrochemical industry from petroleum, natural gas, ethanol, etc. As shown in Figure 9, ethylene is considered a 1st generation product within the petrochemical industry, being produced directly from the mentioned raw materials.

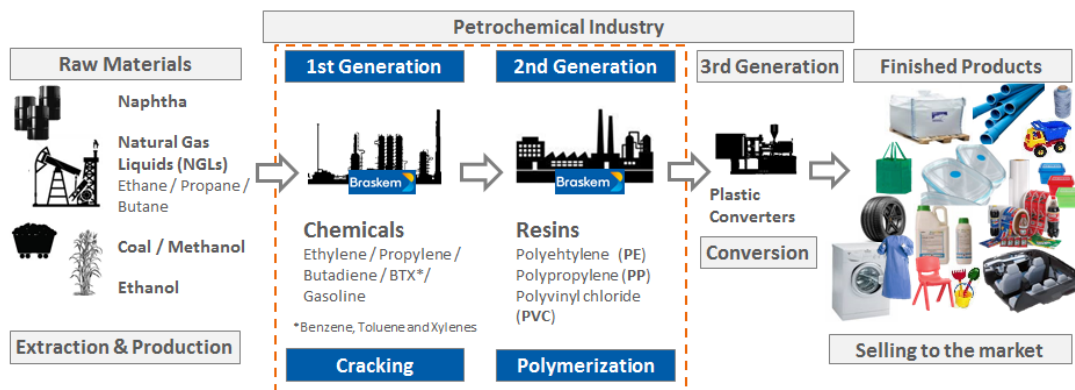


Figure 9. Productive line derived from fossil sources.

Source: Braskem S.A. (2019).

Currently, as described by Pereira, Alves, Furtado, Antunes and Sá (2007), the two processes currently used for the transformation of petroleum products are steam cracking (Steam Cracker) and fluid catalytic cracking (FCC). The FCC is commonly used in the industry because in addition to being a highly flexible process, adjusting to the specific needs the company, it also works with the transformation of medium hydrocarbons (3-12C) into gasoline, LPG and other compounds with high performance economic when they are commercialized, thus making it

interesting at an economic level. To produce ethylene, the use of Steam Cracker is the most used for working with light hydrocarbons (1-2C).

This last process requires a large amount of energy to conduct the reaction and break the bonds, and for the cracking of ethane, vapors of approximately 800°C are required, which are carried out inside pyrolysis furnaces, using steam as a diluent. After such a process, the formed effluent is sent to a heat exchanger and cooled by water currents, for its condensation. The waste is recycled and returned to the pyrolysis furnaces. The effluent formed is treated to remove acetylene and make the separation between ethylene and ethane, the latter being sent back to a recycle that will return to the pyrolysis furnaces. The gases formed in the pyrolysis oven are treated, to remove acid gases, and through a dematanizer, it is possible to obtain hydrogen gas and methane gas, generating more by-products in this process (Chauvel, Lefebvre, Leprince & Marshall, 1989).

Figure 10 identifies the entire petrochemical chain in which it is involved.

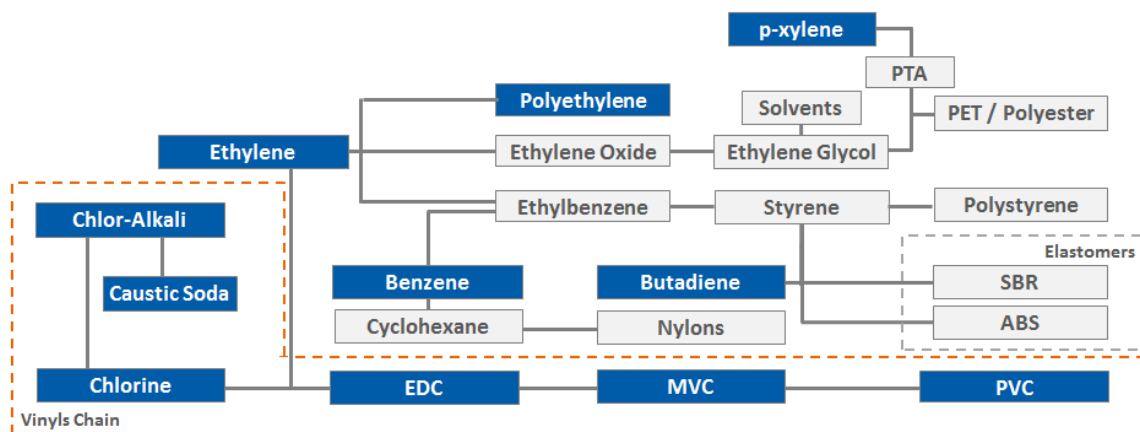


Figure 10. Petrochemical chain of ethylene.

Source: Braskem S. A. (2019).

The market value of ethylene varies according to the petrochemical demand and its own consumption demand, with the credits obtained from the sale of the by-products formed in its production (sales value deducted from the production value) and the location in which it is produced. Therefore, the floor of the world price is established based on the cost charged by the smallest producers, which generally belong to Europe in plants that use naphtha as a raw material (Braskem S.A., 2019).

As shown in Figure 11, worldwide, the price of ethylene produced in the USA (raw material ethane) has the lowest market value in 2018, that is, the cheapest to acquire in relation to other locations.

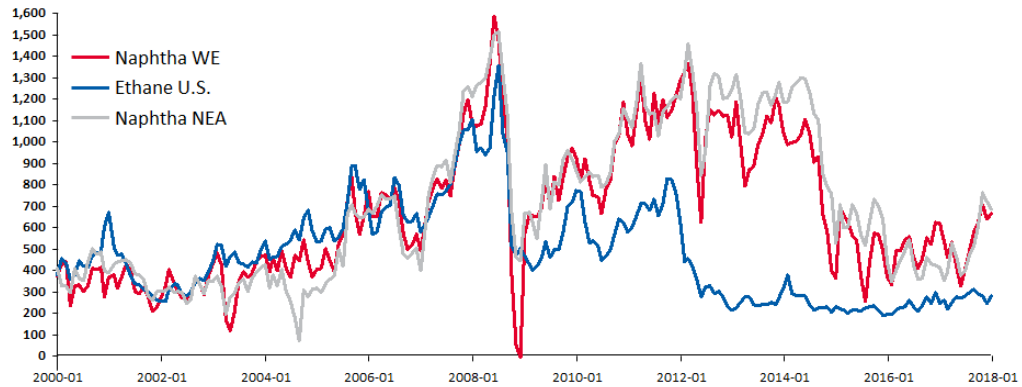


Figure 11. Variation of ethylene prices from 2000 to 2018, in dollars.

Source: Braskem S.A. (2019).

From the Shale Gas Revolution (unconventional hydrocarbon resource) that started in the USA in 2014 (as can be seen in Figure 11 by the decay of the curve from 2008 where it started to be used), ethane became the most advantageous raw material for the production of ethylene in relation to the cost benefit and the value of production and sales in relation to the ethylene produced (Braskem S.A., 2019).

Concerning the transformation between raw materials vs. product, the use of ethane is also more attractive, as, as shown in Figure 12, to produce 1 unit of ethylene, 1.3 units of ethane are needed (disregarding its by-products). As for naphtha, for each unit produced of ethylene, 3.3 units of naphtha are used (and even if the formation of by-products acts, the amount does not reduce to the amount spent making it more expensive than ethane).

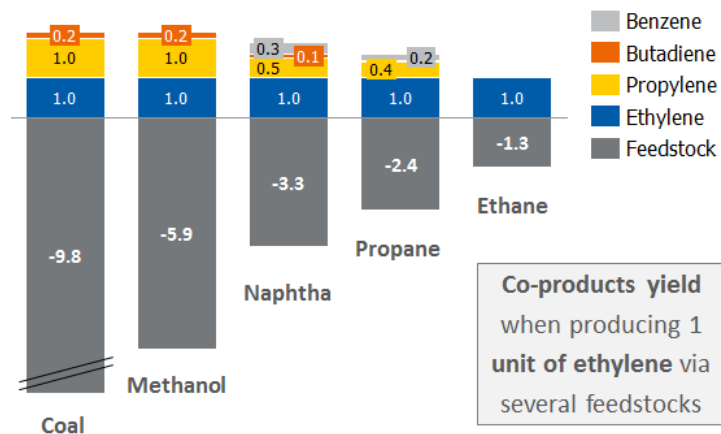


Figure 12. Relationship between quantity of raw materials used vs. ethylene produced.

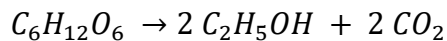
Source: Braskem S.A. (2019).

### 3.3.1.3. Ethene from natural sources

Green polymers can have different sources of raw material, and they must necessarily be renewable, such as sugar cane, corn, cereals, etc. From these, it is necessary to obtain ethanol, which in turn, through chemical processes, will be transformed into ethylene, the raw material to produce PVC. Therefore, in general, the generation of green ethylene is made from the production of ethanol by biomass.

The raw materials used are classified into three classes: The first is called *Saccharides*, they are all raw materials that contain sucrose, such as sugar cane, beets, molasses, and fruits. The second is *Amiláceas*, raw materials that contain starch, which must be hydrolyzed for the generation of sugars and the third, called lignocellulosic, and through lignocellulosic biomasses such as wood, straw, sugarcane bagasse, factory waste of paper, etc. will be converted into ethanol by treatment with hydrolysis and microorganisms (Galvez, 2005).

Production begins with the treatment and extraction of sugar, regardless of biomass, which varies according to the matrix in which it will be used, being then directed to the fermentation where the transformation of glucose ( $C_6H_{12}O_6$ ) into ethanol ( $C_2H_5OH$ ), as shown in Equation 2 below:



Equation 2.

Among the sugars that can be fermented can be mentioned the glucose, fructose, mannose, and galactose monosaccharides, being that the microorganism responsible for the alcoholic fermentation for the production of ethanol is the *Zymomonas mobilis*, for example. Although polysaccharides such as starch and cellulose cannot be metabolized by yeast, through alterations in the lineage of the microorganism *Saccharomyces cerevisiae*, such polysaccharides have become capable of being used as a basic raw material for the production of ethanol (Galvez, 2005).

Regarding the fermentation shown by Equation 2, the ethanol generated presents a percentage around 12%. In order to have a higher concentration in its percentage of alcohol, which will result in a higher yield in the future transformation into ethylene, the solution is sent for distillation, which allows it to reach a concentration of 96% (Cameron, 2016).

Then, with the bioethanol in the appropriate percentage in relation to the alcoholic content, the dehydration process will be directed, being carried out in the steam phase using fixed bed or fluidized bed reactors, to obtain the bioethene (Kochar, Merims & Padia, 1981). Figure 13 demonstrates the production process of dehydrating ethanol to form ethylene.

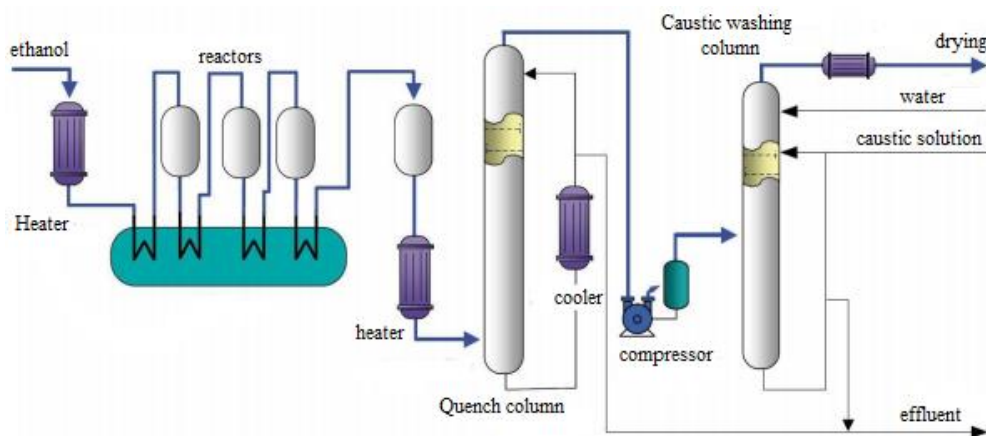


Figure 13. Productive process of ethanol dehydration.

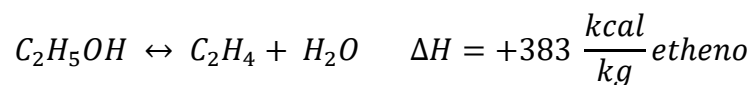
Source: Adapted from Polizeli (2012).

The ethanol dehydration process, as shown in Figure 13, begins with the preheating of the ethanol by a stream of steam to the desired temperature for the process. Then, the mixture of

ethanol and water vapor, in proportions of 1: 2 or 1: 3, is directed to a series of fixed bed reactors in series with intermediate furnaces where catalytic dehydration will occur (Kochar et al., 1981).

The process is endothermic, requiring the absorption of external heat for it to occur, and such heat must be carefully controlled for the reaction to proceed smoothly. In this reaction, it is commonly used, for example, water vapor, which in addition to entering the reaction as an inert gas, helps in controlling the internal temperature of this reaction. This control is necessary because the reaction of ethylene formation is favored with temperatures between 360 to 500oC, and below this temperature there is the possibility of formation of unwanted products, such as ethyl ether and temperatures above that indicated, there is no interference in the reaction, in addition to that, the use of steam also contributes to preserve the useful life of the use catalyst (alumina or silica-alumina) and therefore, its yield over time (Kochar et al., 1981).

Therefore, as mentioned above, heat absorption occurs during the chemical reaction, which occurs in a single, reversible step, shown by Equation 3.



Equation 3.

In the event of the formation of by-products with parallel reactions, which for the most part can generate acetaldehyde, hydrogen, acetic acid, carbon monoxide, carbon dioxide, etc., these are sent for recycling, avoiding costs and contamination in the final product (Morschbacker, 2008 ).

The unreacted ethanol also returns for recycling; However, the typical conversion rate of the process is around 95 to 99%. After the reaction, the product is directed to a caustic washing with sodium hydroxide to eliminate carbon dioxide residues in the product and then sent to the desiccant bed to obtain the ethylene with a high degree of purity (99%) (Kochar et al., 1981).

The energy consumption of this process is 2GJ/t, however, depending on the installation, consumption can reach up to 5 GJ/t. To produce 1 ton of bioethene, dehydration of 1.74 tons of bioethanol is required (Cameron, 2016).

Regarding the cost involved, factors such as biomass used, production logistics and infrastructure used influence the total value that bioethylene will assume. Figure 14 shows the cost

of producing ethanol from biomass using the United States, Europe, and Brazil in 2006 as a reference.

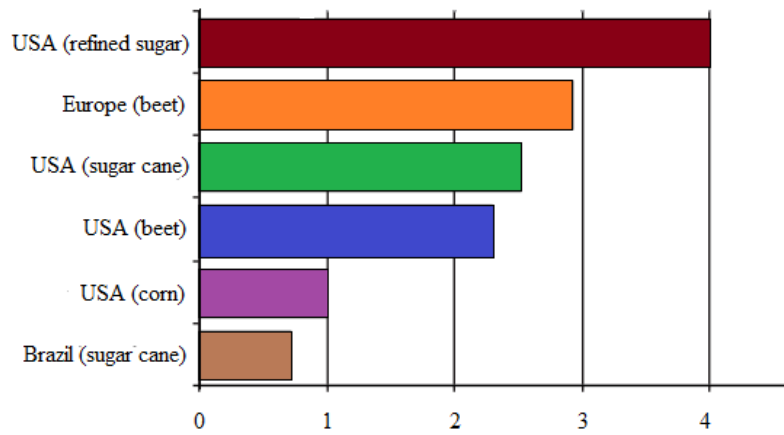


Figure 14. Cost of ethanol production from different biomasses, in dollars.

Source: Adapted from Bastos (2006).

As it is possible to identify, the costs of bioethanol production in Brazil are, in relation to Europe and the United States, the lowest, when compared to the refined sugar, beet, corn and sugar cane matrices. This is mainly due to factors external to production, that is, factors such as area and quantity of production and the cost of maintaining it are mainly responsible. However, it is important to mention that in 2006 until the present day, the United States and Europe are investing greater resources in research involving green fuels, which, in parallel, is the investment in research on bioethanol and green ethanol than Brazil (Bastos, 2006).

Figure 15 shows the relationship between the price of green ethanol and its main sources of raw materials used worldwide (sugar cane and corn) as well as a forecast considering demand and current consumption of the material.

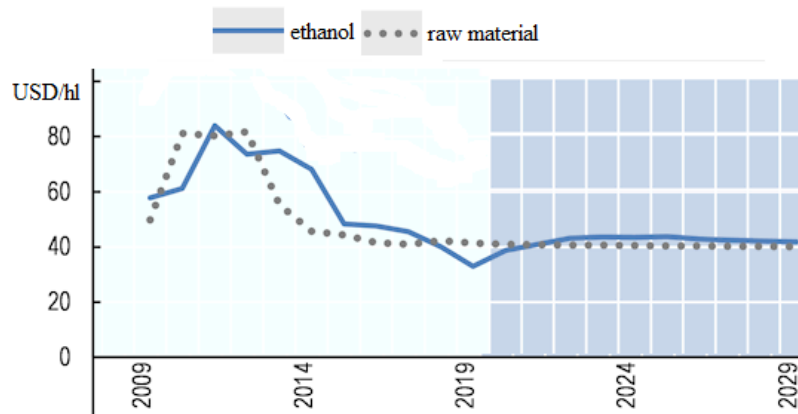


Figure 15. Price prediction of green ethanol and its raw materials.

Source: Adapted from Organization for Economic Cooperation and Development and the Food and Agriculture Organization of the United Nations (2020).

As it is possible to observe, the forecast made is that there will be a linearization in relation to the values between raw material and green ethanol production. This is mainly due to the possible stagnation in investments made in the United States, due to new sources of fossil materials explored, such as shale. According to Organization for Economic Cooperation and Development and the Food and Agriculture Organization of the United Nations (2020) the expectation is that from 2026 the price will decrease, but with greater investments in Europe and Brazil due to the exploration of new sources of raw materials.

Another expectation presented is in relation to the raw materials used, and currently, sugarcane and corn are the most used to produce bioethanol and green ethanol. It is predicted that by 2029, about 25% and 14% of all production of such materials, respectively, will be destined exclusively for the production of green ethanol, where the latter may be sent to the production of diesel, ethylene, among other products that the same is the basis for production (Organization for Economic Cooperation and Development and the Food and Agriculture Organization of the United Nations, 2020).

### 3.3.2. Production - vinyl chloride monomer

The reaction to obtain the vinyl chloride monomer is obtained through the reaction between chlorine and ethylene. Its production can be carried out through three different routes, namely the

ethylene/chlorine route or balanced reaction, the acetylene route and the ethane route, the latter of which is still under development (Wieme et al., 2007).

The acetylene route was used as the main route, mainly in Europe, until the 1960's due to the wide availability of raw material at the time and because it had the lowest cost for the installation of its production plant. However, currently, when comparing the prices of obtaining raw materials, the production value of ethylene is lower compared to acetylene, making the process less economically viable (Nass & Heiberger, 1986).

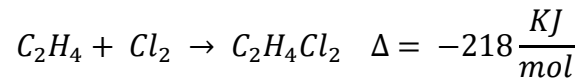
Alternative routes are under development, considering the base raw material for it and all the financial costs that are involved in obtaining and using it. In this context, the ethane route is being developed. This route proves to be economically more viable as it can be obtained directly from oil, natural gas or from matrixes from renewable sources, without having to undergo chemical treatments (Wieme et al., 2007).

The chlorine/ethylene route covers about 90% of the processes that currently involve the production of the monomer. This route is based on a process with balanced reactions, where all reagents, intermediates and by-products go through the process again for the only product formed is the monomer (Dimian & Bildea, 2008).

### **3.3.2.1. Chlorine / ethylene route**

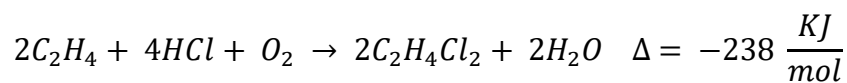
The chlorine/ethane route occurs in two routes to produce the vinyl chloride monomer, MVC, both of which are based on the intermediate product 1,2-dichloroethane or EDC. The intermediate product formed is sent to a furnace to undergo thermal cracking and thus form the MVC.

The general process for forming EDC is divided into two main reactions. The first, represented by Equation 4, is called direct chlorination where ethylene reacts with chlorine to form DCE (1,2 dichloroethane). The physical conditions for its production vary between the phase it is in, in the gas phase the temperature is between 90 to 130°C and pressures from 7 to 10 atm, and in the liquid phase temperature between 50 to 70°C and pressure from 4 to 5 atm (Rodolfo Jr. et al., 2006).



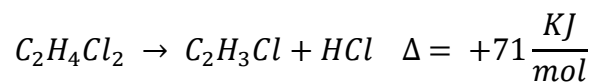
**Equation 4.**

The second reaction, represented by Equation 5, is the oxychlorination of ethylene, where it is catalyzed by copper chloride, with a temperature between 250 and 350°C. The conversion of this equation can present better results if there is the addition of oxygen, leading to a higher partial pressure in the system (Rodolfo Jr. et al., 2006).



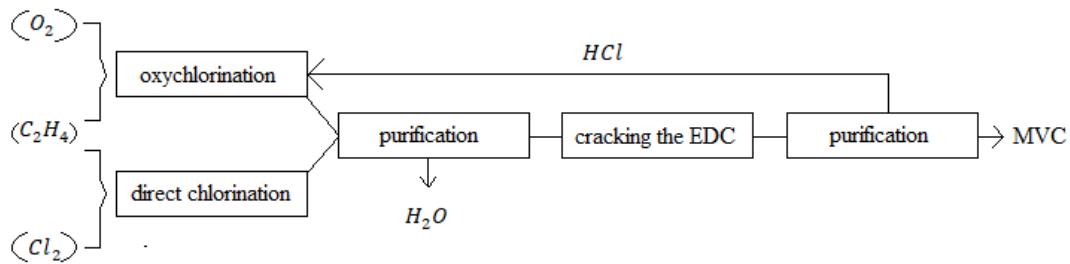
**Equation 5.**

After the formation of the EDC by the routes shown, it is directed to furnaces that should be at temperatures between 470 to 540°C and pressure, for liquid cargo between 24 to 26 atm and vaporized loads from 4 to 10 atm, to undergo thermal cracking. Equation 6 demonstrates the reaction that occurs in thermal cracking that generates hydrochloric acid (HCl) and monomer (MVC) as products (Rodolfo Jr. et al., 2006).



**Equation 6.**

The chlorine/ethylene route is also known as a balanced route because in the process line it is fed with the EDC produced by the two reactions in a proportion of 50% so that the relationship between consumption and hydrochloric acid generation is balanced, that is, the same amount consumed in relation to reagent and product formed during the process, as shown in Figure 16. To decrease expenses and increase yield, DCE is recycled, returning to the chlorination stage, to guarantee a greater conversion of the reagents into the monomer. (Rodolfo Jr. et al., 2006).



**Figure 16.** Monomer production process by the chlorine / ethylene reaction.

Source: Adapted from Rodolfo Jr. et al. (2006).

According to Kahsnitz, Schirmeister and Trager (2009), thermal cracking must be carried out until a conversion between 55 to 63% is achieved, which corresponds to a selectivity of 98 to 99% of MVC formed. If this conversion is greater, there will be the formation of by-products such as acetylene and benzene, which cannot be returned to the process through recycling. Rodolfo Jr. et al. (2006), mention that, such conversion must be between 60 to 70% to achieve the same results described.

With boiling temperature at  $-14^{\circ}\text{C}$ , the monomer forming is a gas that has a high vapor pressure when exposed to room temperature, therefore, its control must be done in a rigid way, because in addition to being toxic it is also carcinogenic (Rodolfo Jr. et al., 2006).

### 3.3.3. Polymerization synthesis of Poly(vinyl chloride) - PVC

Currently, about 90% of the world's production of PVC is carried out through the aqueous phase suspension polymerization process, which is considered the most important due to the high yield of the conversion rate between reagent and product. Other methods used are those of emulsion or microsuspension, corresponding to 5.7% of the total PVC produced (Hill, 2000; Wieme et al., 2007).

The processes that use the solution and mass method, which corresponds to about 1.8% of the total, have little representativeness due to the high cost of the process and the low profitability in relation to the others. The remainder of the percentage represents processes that do not produce PVC copolymers, such as those produced by solvent polymerization (Rodolfo Jr. et al., 2006).

Figure 17 represents the production of poly(vinyl chloride), in a general way. Still considering the process in a general way Bohnet (2003) describes that, regardless of the polymerization method used, the reaction, represented by Figure 18 is endothermic, with specific heat of approximately 1,352 J/kgK. That is why, due to the high temperature that the process reaches, it is necessary to use equipment to control it, such as a condenser or cooling jacket in the reactor. Depending on the process, it is possible to have a reflux condenser so that the monomer is condensed and returned to the reactor in a liquid state, avoiding losses.

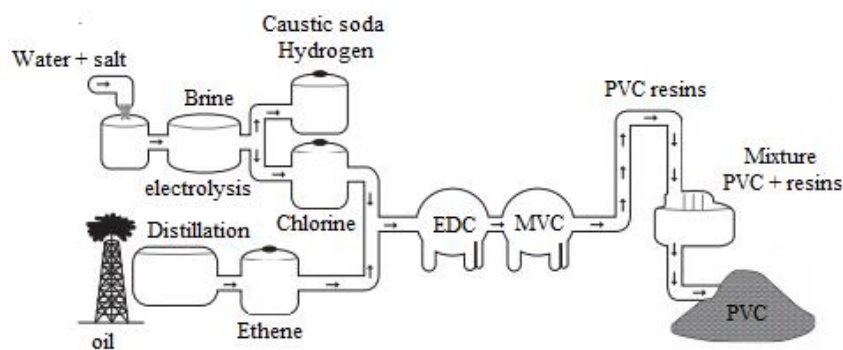


Figure 17. General PVC production.

Source: Adapted from Pereira (2014).

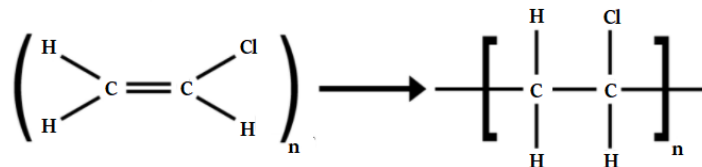


Figure 18. General reaction of polymerization of the monomer in PVC.

Source: Adapted from Summers (2006).

During the process shown in Figure 17 it is incorporated together with the paste generated by the mixture of the raw materials, the additives. These are subdivided according to their function, the most common being stabilizers, lubricants, and pigments. Plasticizers are the most common additives to be added to PVC, promoting a reduction in hardness and an increase in its flexibility. The most widely used plasticizers are phthalates, with emphasis on DOP (dioctyl phthalate), BBP (butyl benzyl phthalate), DBP (di-butyl phthalate) and DNOP (di-n-octyl phthalate). It is important

to note that, for each production, specific additives are added to assign specific characteristics to the final product (Wieme et al., 2007).

### **3.3.3.1. Suspension polymerization**

In relation to the other types of polymerization mentioned, suspension polymerization has the advantage of high productivity as well as high yield, flexibility in the composition of the polymer used in conjunction with its characteristics and the ease in controlling the heat generated by the reaction and also in its removal when necessary (Silva & Gois, 2013).

The suspension process begins by adding the monomer inside the reactor, which is dispersed in the form of drops with an average diameter between 30 and 150 micrometers, in an aqueous phase, with demineralized water, together with initiators (soluble in the monomer used) and the suspending agent, under constant agitation. An important point to be carried out at the beginning of the process is the need to keep the reactor without oxygen, in a vacuum, as this can interfere with the process, which may increase the reaction time and change the properties of the final product (Wieme et al., 2007).

The main function of agitation and the suspending agent (which can be called dispersing agent or protective colloid) is to keep the process thermodynamically stable and not to allow coalescence between the phases (Silva & Gois, 2013).

A point to be considered at this stage is the proportion added in relation to the components described, and any change in the indicated quantity, as can be seen in Table 1, will result in characteristics that may compromise the final product. According to Bohnet (2003) water is only used in the reaction as a reaction medium, not actively participating in the reaction, however, when it is an unbalanced proportion in relation to its proportion with the monomer, there is the generation of PVC particles of varying sizes, without any kind of control or adjustment between them. On the other hand, when there is an unevenness ratio where PVC is above the indicated amount, in addition to causing instability in the reaction medium, it will affect the final characteristics of PVC, such as its porosity and apparent density.

**Table 1.** Standard procedure for polymerization of PVC in suspension.

Section	Quantity (in relation to VCM)
VCM	100%
Water (deionized)	100 - 120%
Suspension agents	0.05 - 0.1%
Initiators	0.03 - 0.16%

Source: Adapted from Alsopp, 2003.

The added suspending agents can be divided between primary and secondary. The primary has the function of defining the size of the PVC grain and the secondary aims to control the morphology of the PVC, that is, to guarantee uniform porosity, less coalescence for the system, to maintain thermal stability in addition to ensuring greater MVC desorption unreacted in the system, contributing to its return through the appropriate recycling and avoiding the formation of foams inside the reactor (Bohnet, 2003; Rodolfo Jr. et al., 2006).

In relation to the initiators, its function is to promote the lack of electrons in the system thus triggering the grouping of monomers. Some factors of the process influence the choice of the initiator to be used, for example, the way in which the solubilization will occur in the medium in which it will be inserted, the temperature at which the process will work, the speed at which the initiator will arrive in its half life and the final characteristics that the PVC will have, etc. Usually in the process, an initiator is used at the beginning of the reaction, which acts faster to help the beginning of the reaction as a whole, and a slower one, which will be activated when the first loses its activity completely (Bohnet, 2003).

Usually, the polymerization temperature is 45 to 75°C. According to Coelho, Gonçalves, Dionísio and Gil (2006) the polymerization temperature is directly proportional to the conversion and the characteristics that the PVC will assume. With higher temperatures, there is a greater clash between molecules which results in smaller polymers, therefore less molar mass and with high conversion. At low temperatures, there is less shock between molecules, generating polymers with greater molar mass but with instability in the percentage of conversion. Therefore, there are cases in which the process takes place at lower temperatures, in order to have greater stability between the molecules. However, in order to have greater conversion, specific starters are used that will bring such a result.

Figure 19 represents the complete flowchart of PVC production using the suspension polymerization method, previously considering the VCM formation reaction.

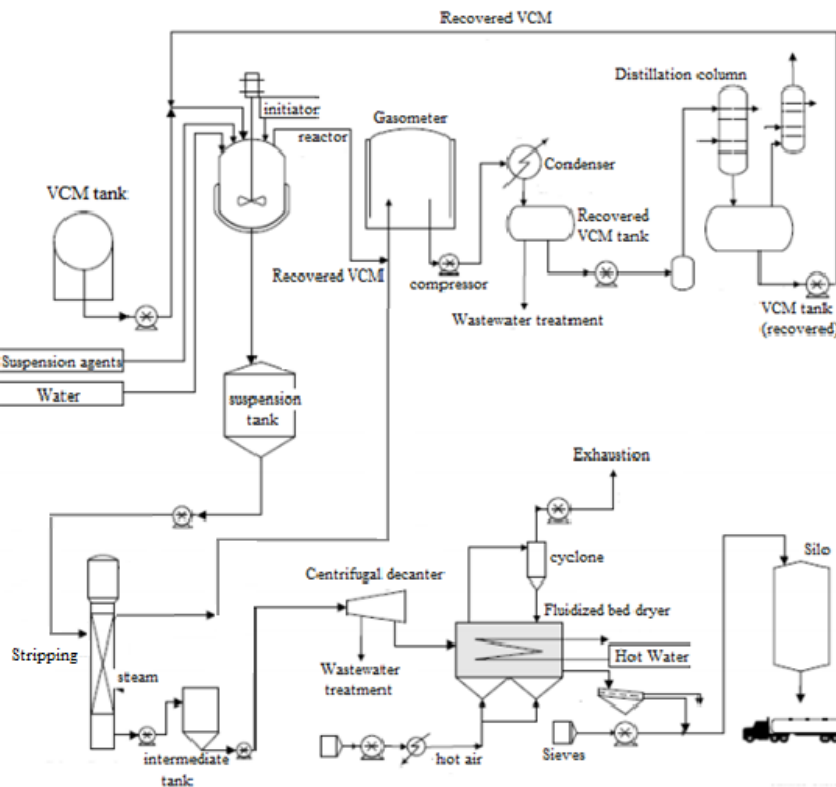


Figure 19. Flowchart of the PVC production process in suspension.

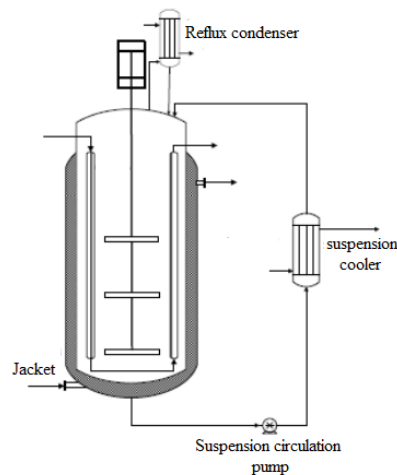
Source: Adapted from Saeki (2002).

After adding the reagents and starting the polymerization reaction, the reactor is heated between 45 to 75°C, where the temperature varies depending on the type of final characteristic that you want to give to the PVC. The temperature control of the reactor is done by a jacket with constant water circulation or condenser, which is why the monomer will return to the reactor when condensing (Wieme et al., 2007).

The generic reaction, shown by Figure 18, is exothermic (around 1540 kJ/kg) and occurs in high volume reactors (between 50 to 200 m<sup>3</sup>). Therefore, if there is heat accumulation and therefore its uncontrolled, it will result in more process time (Bohnet, 2003; Rodolfo Jr. et al., 2006).

Figure 20 schematically represents the suspension polymerization reactor described above. As indicated by Saeki and Emura (2002), the polymerization reaction takes place in a reactor made

of stainless steel. For the formation of PVC with a molar mass of 55 g/mol, a residence time (of the entire transformation process) is required for 8 hours, a temperature of 75°C and a pressure of 5kgf/cm<sup>2</sup>, and this pressure tends to decrease with increasing conversion. It is important to mention that the PVC resin described by Saeki and Emura (2002) has a molar mass of 55 g/mol thanks to the characteristics that the process had, including temperature and pressure. However, other conditions can be applied for polymerization, as long as they are suitable for the process equipment.



**Figure 20.** Scheme of the suspension polymerization reactor.

Source: Adapted from Manual Integração CIRES (2006).

At the end of the reaction, the system pressure decreases, due to the consumption of the monomer and an increase in the quantity of the product (around 85 to 90% yield), thus indicating the end of the polymerization (Alsopp, 2003).

Figure 21 shows the relationship of temperature inside the reactor, pressure and jacket temperature for a reaction that occurs around 75°C. As already mentioned, and which can be observed by the figure, initially there is an increase in the temperature of the jacket so that it can help in increasing the pressure and increasing the internal temperature of the equipment.

During the reaction, the internal temperature remains constant as well as the pressure, and for this reason, to help regulate the temperature, there is a compensation in the temperature of the external jacket. When the expected conversion of the reaction is reached, the pressure decreases and together there is a momentary increase in the jacket temperature so that the internal

temperature remains constant. Such temperature must be constant to assist and deformations do not occur in the newly processed material. The conversion point can be stipulated depending on the material used as raw material, quantity, and conditions of the reactor.

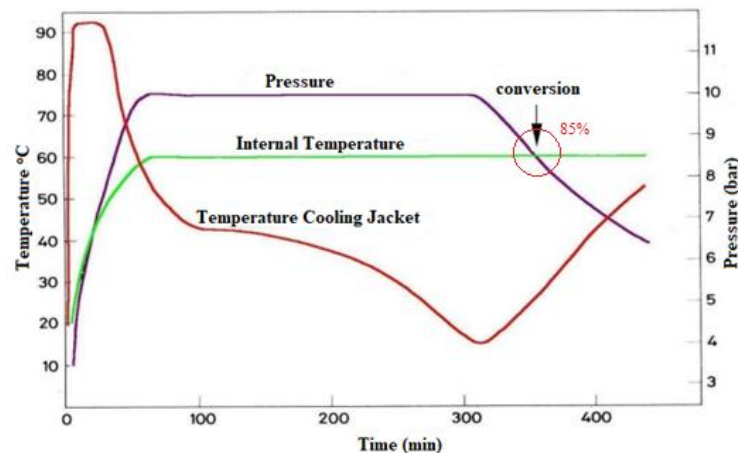


Figure 21. Evolution of pressure and internal temperature of the reactor and jacket temperature during polymerization.

Source: Adapted from Endo (2002).

The polymer formed, as described by Rodolfo Jr. et al. (2006) has around 2 to 3% of MVC grouped with it, and this set is called mud. After the reaction, the sludge is directed to the suspension tank to separate the mixture and, then, it is directed to the stripper to separate the unreacted monomer and formed resin using the reduction of the total pressure of the system together with the increase in temperature, later being liquefied and returning to the process.

In total, to proceed, the resin formed must contain a maximum of 1 ppm of monomer, according to the ASTM D3749 standard, as higher concentrations are carcinogenic. Then, the sludge containing only PVC with water is sent to a centrifuge, which will lose approximately 80% of water after the process, and then sent to the fluidized bed dryer to eliminate the rest of the water and, subsequently, to the sieve. Finally, having only PVC resin, it is sent to a storage silo where it will be prepared for sale and commercialization (Rodolfo Jr. et al., 2006; Tigrea & Santos, 1992).

In addition to being cancerous and having the economic factor involved in the recovery of VCM, another factor that must be considered is the restrictions on its disposal. Because it is a gas, when released with the product, in a higher percentage than allowed, in addition to blocking the final product from being able to be sold, it can momentarily and in the medium term seriously affect serious problems to workers and the company as a whole, therefore, the industries maintain

a continuous policy of progressive reduction of emissions of this monomer, either during the process, either in the final product or in the effluents emitted (Alsopp, 2003).

In 1974 there was the first report that related human exposure to the monomer with the appearance of cancer. As a result, the need for regulation increased both during the process and in the quantity emitted in the effluents and in the final product (Borrelli et al., 2005).

Legislation inspects both the final product and industry conditions to see VCM levels, indicating maximum residual monomer emission targets, as shown in Table 2.

**Table 2.** VCM emission limit

<b>Emission types</b>	<b>Allowable quantity</b>
Total VCM emission in PVC production	< 100 g.ton <sup>-1</sup>
VCM concentration in liquid effluents	< 1 g.m <sup>3</sup> effluent
Concentration of VCM in gaseous effluents	< 5 mg.Nm <sup>-3</sup> effluent
Concentration of VCM in the final product	< 5 g.ton <sup>-1</sup> (general use)
	< 1 g.ton <sup>-1</sup> (medical / food use)

Source: Official Journal of the European Communities (1978).

For this reason, within the PVC production plant, there are two paths that involve the post polymerization monomer: The first is the installation of a monomer recovery unit, as shown in Figure 19 and detailed in Figure 22 below and the installation of a treatment equipment in order to remove the excess monomer that may be linked with the PVC mass previously ready as already explained above.

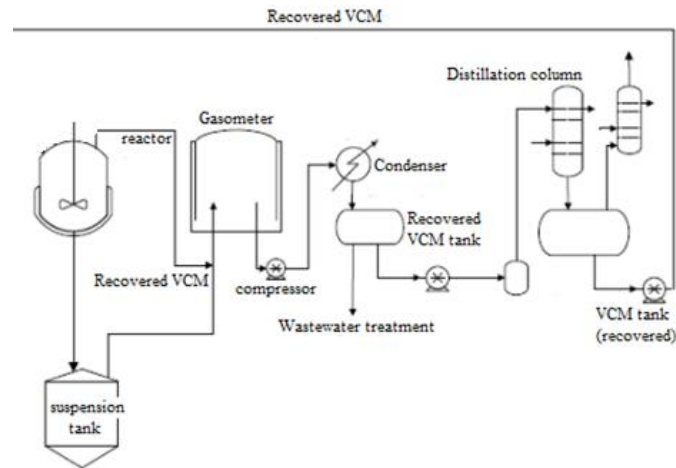


Figure 22. VCM recovery in the PVC production process via suspension polymerization.

Source: Adapted from Saeki (2002).

The VCM that did not react inside the polymerization tank and the one that managed to undergo physical separation inside the suspension tank is sent to the gasometer whose purpose is to store the gas at room temperature and atmospheric pressure. Within itself and in a functional process, its content is approximately 98% unreacted VCM and other compounds or impurities such as methyl chloride ( $\text{CH}_3\text{Cl}$ ), ethyl chloride ( $\text{C}_2\text{H}_5\text{Cl}$ ), nitrogen ( $\text{N}_2$ ) and oxygen ( $\text{O}_2$ ) (Alsopp, 2003).

The current that comes out of the gasometer is sent to a compression unit where its pressure, after equipment, reaches 7 bar. This pressure increase is necessary so that, when it reaches the condenser, the gas can be treated with the coolant at high temperatures (Alsopp, 2003).

The condensing unit uses water as a cooling fluid, and it is separated into two distinct stages: The first operates at a temperature of  $25^\circ\text{C}$  and the second at a constant temperature of  $8^\circ\text{C}$ . The gas enters the first stage and the remains of the product that did not condense go through the second stage, thus ensuring that all the gas will condense. Then, the VCM is sent for cryogenic treatment and sent to the recovered VCM tank, thus being able to be reintroduced into the process (Alsopp, 2003).

Regarding the MVC removal methods in PVC, there are two that are most used, this being the chemical, where other compounds are added to react with the monomer and make it easier to remove or the physical, which can be used a stripping tower (more usual) or by other methods that can use extractions by solvents, ionic resins or volatilization (Silva & Góis, 2013).

The stripper is the most used option in industries today because it does not degrade PVC when used, it also has the entire automated process. According to Gilbert and Patrick (2017) when using the method, any monomer that is grouped with PVC can be recovered and, after being purified, can return to the process.

## **4. Fictional company: BiPlastic**

From the methods and processes used in the industries of the petrochemical sector focused on the production of plastics and commercial resins presented, in this section, the process that the fictional company BiPlastic will adopt will be exposed, considering all the specifications for its green PVC production process.

### **4.1. Productive process**

For the construction of the investment evaluation in a company producing green PVC resin based on sugar cane, a fictitious company, called BiPlastic, will be molded, after which the entire business plan will be built as well as its financial analysis. To assess whether the project to install a green polymer company in Portugal is financially viable or not for the construction of its production process, assumptions will be used in relation to the inputs and outputs of the process, however based on the production of companies that already exist in the market and on the desired turnover and final production.

Therefore, in relation to the production process, the information structured in section 3.3.3. will be considered, both in relation to the PVC resin production process and in relation to the MVC recovery process.

Figure 23 demonstrates the simplified suspension polymerization process that will be used as the basis of the BiPlastic green PVC production process. For the recovery of the MVC, according to Allen and Baker (2003), only the use of a Stripper tower, with a temperature range between 92°C and 132°C at atmospheric pressure, will be sufficient. When using it, the newly produced PVC sludge will be separated without suffering degradation of the monomer residues, reaching a margin of 0.5 ppm, an amount accepted by law.

Although other equipment, to refine the treatment, can be implemented as observed by the general process in Figure 19, as the process proposed by BiPlastic will be of low demand compared to the companies in the sector used as a base, it was preferred to follow the basic process presented by Rodolfo Jr. et al. (2006).

It is important to emphasize that, as the company will start its processes based on such data, entering the market as a new brand and not yet consolidated by the public, therefore the volume of production will also be lower, when compared with possible competitors. For the calculation basis, the main equipment in the production process and in the recovery, process will be evaluated.

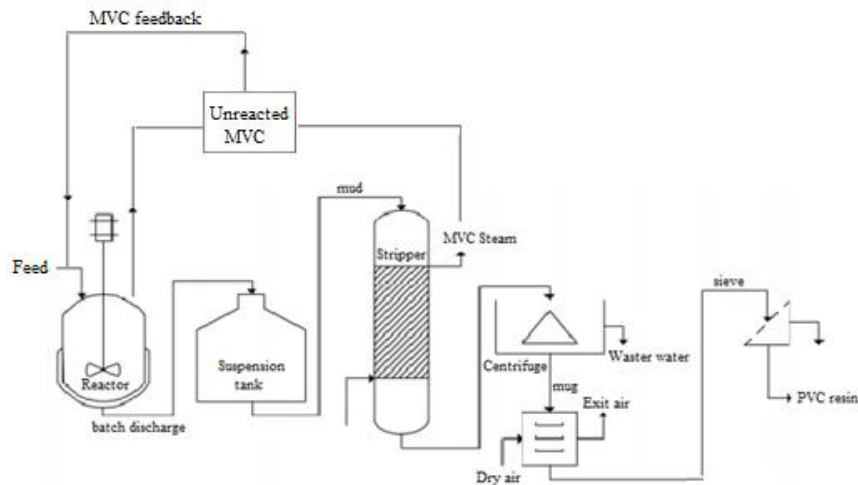


Figure 23. Simplified production process of poly (chloride) of vinyl by suspension.

Source: Adapted from Rodolfo Jr. et al. (2006).

Therefore, from the simplified process shown in Figure 23, a block diagram shown in Figure 24 will be carried out, so that the mass balance of the process will be developed. The equipment and their respective symbols within the diagram are: agitated batch reactor ( $R_1$  e  $R_1'$ ), suspension tank for receiving batches and transformation of the system to continuous process ( $T_1$ ), stripper for recovery of unreacted MVC ( $S_1$ ), unreacted monomer storage tank ( $T_2$ ), centrifuge ( $C_1$ ), dryer ( $Sc_1$ ) and sieve ( $B_1$ ).

As already mentioned, data such as the expected estimate of the capacity of the process, mass in kilogram (kg) of reagents entering the reactor and the sizing of the equipment will be done in order to shape the base project, with data from the literature but, when applied in real life, may change.

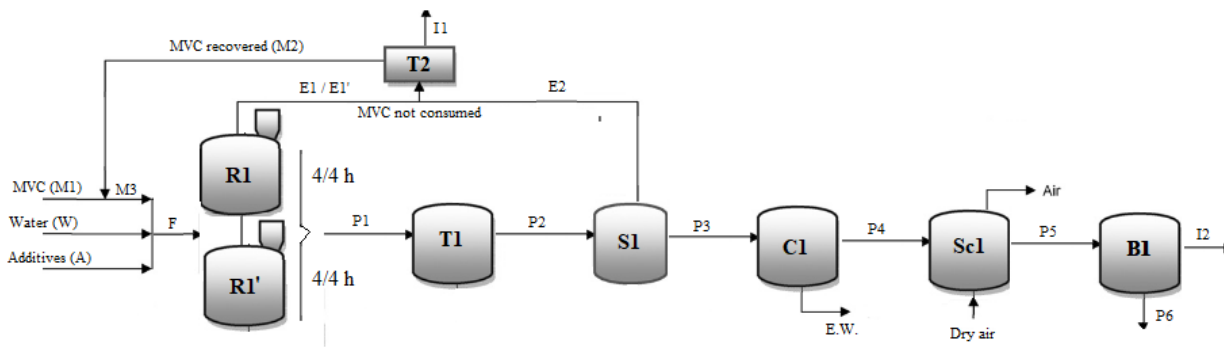


Figure 24. BiPlastic production process block diagram.

Source: Adapted from Tacidelli (2009).

In the following sections, the productive capacity of the process will be defined so that, with such data, it is possible to carry out mass balances from Figure 24.

#### 4.1.1. Definition of productive capacity

BiPlastic's productive capacity will be measured considering two aspects: the target audience that the company will reach, and the amount of PVC produced by its competitors.

When we portray the current production of poly(vinyl chloride), it must be taken into account that companies in the polymer industry are highly matured both in terms of their production and in relation to their customers.

Currently, large companies that produce polymers work with different resins and not just in a specific product or process using oil as the main source of raw material. However, with the emergence of new environmental laws that govern such an area together with the emergence of a new consumer public, amplified by the concern with the finitude of the raw material in relation to the proportion to its consumption, it is leading to the exploration of new sources for the replacement oil. Companies with Braskem have already proposed plans to replace oil and become a company focused on the green market. As already mentioned, the company invested around US\$ 61 million in expanding the production of biopolymers for its subsidiaries located in Brazil (Braskem S.A., 2021).

Therefore, bringing in its concept of idealization the word innovation, BiPlastic intends to be the first company to bring green policy in all its sectors of activity, working with renewable

raw material sources that make PVC green in addition to reducing the quantity of CO<sub>2</sub> formed in the process thanks to the carbon cycle involved in planting/maturing the base raw material.

In relation to Braskem, according to data from Magnabosco (2014), the production of poly(vinyl chloride) was approximately 200 thousand tons / year per unit of the company. The company has a total of 3 PVC producing units, but none of them are geared to production from other raw materials other than oil.

In Portugal, the only company that can be treated as a direct competitor to BiPlastic is Companhia Industrial de Resinas Sintéticas, CIRES, which produces, among other products, PVC resin from fossil sources. Even though marketing and product targeting have a market proposal, due to its maturity and established name, CIRES is the main competitor that BiPlastic will have within the Portuguese market.

Data released by the company report that the production of PVC resin by suspension polymerization was 200 thousand tons / year and, therefore, approximately 17 thousand tons per month (CIRES, 2017).

Another fact to be considered is the amount of plastic currently consumed. In 2019, world consumption of plastic was approximately 368 million tonnes, whereas in Europe alone consumption was 57.9 million tonnes (PlasticEurope, 2020).

Therefore, taking into account the quantity produced by competing companies and that BiPlastic will be a company with a green policy geared towards the consumption of an established target audience, the initial production will be much lower in relation to the other companies in the sector. Table 3 highlights the quantity that will be produced in relation to the annual (330 days) and monthly (12 months) production of the fictitious company BiPlastic.

**Table 3.** BiPlastic's green polymer production ratio

<b>Production</b>	<b>Desired quantity</b>
Annual (330 days)	800,000 kg
Daily	2,424.2 kg

Source: Own elaboration

Based on the value of 800 thousand kg as the company's annual production, according to the quantities presented in Table 1 of the raw materials for PVC production, the supposed values

that will be used to satisfy BiPlastic's production per year will be measured, which is shown in Table 4.

A detail that must be emphasized is that the raw material values accompany the monomer input value. As the quantity expected for the annual production of the product is 800 thousand kg, the same amount in monomer will be necessary, and the other raw materials will be calculated based on such value.

For the construction of the business plan, the costs involving the raw materials used in the process must be calculated. From the calculations and considerations that will be carried out in this section, the real yield of the process will be determined and, from that value, the real value of the raw materials that will be used to achieve the annual production of 800,000 kg of green PVC resin will be found.

**Table 4.** List of raw materials required for BiPlastic's annual production

<b>Raw material</b>	<b>Required quantity</b>
Vinyl chloride monomer	800,000 kg
Water	800,000 - 960,000 L
Suspension agents	400 - 800 Kg
Initiators	240 - 1,280 Kg

Source: Own elaboration.

#### **4.1.2. Calculation Report**

After defining the expected production capacity that BiPlastic will have in its first year, based on data from the literature already explained in section 3.3.3., Some considerations regarding the process conditions will be adopted for the production of BiPlastic, as shown in Table 5. Next, the equipment's mass balance as well as its preliminary dimensioning will be exposed. It is important to mention that, the value of the yield of transformation of the monomer into polymer was considered the lowest percentage indicated by Alsopp (2003), being therefore assumed a value of 85% of conversion for the process. Regarding the percentage of monomer in the mud that is directed to the stripper, the highest value reported in the literature (3%) was used, as it is also possible to identify in the table below.

**Table 5.** Conditions of the PVC production process by BiPlastic

<b>Process conditions</b>	
Heat inside the reactor	75 °C
Pressure inside the reactor	5 Kgf/ cm <sup>2</sup>
Expected molar mass of PVC	55 g/ mol
Total batch time	8 hours
Reaction time	6h 30min
Yield in the reactor	85%
Percentage of monomer in the mud in the stripping	3%
Percentage of monomer recovered within the process	98%

Source: Adapted from Hamilton (2013).

As you can see from Figure 24, there is a system in relation to the reactors called  $R_1$  e  $R_1'$ . Such a system was created considering the reaction time that occurs during the polymerization and the dimensioning of the equipment that will be used in the production. In total, 4 reactors will be used, and these will be separated in pairs ( $R_1$  corresponds to 2 reactors and  $R_1'$  to the other 2). Each pair will start production at an interval of four hours, that is, every four hours, the product will be sent to the produced storage tank, which, in turn, will be releasing the product for the rest of the process. Therefore, the calculation report will be considering the entry and exit of the system based on the total volume of each reactor pair.

#### **4.1.2.1. Reactor Calculation Report ( $R_1$ )**

As you can see from the block diagram in Figure 24, the batch reactor has as input the monomer feed (F), water (W) and additives (A) and two outlets, the first being for the post-polymerization product ( $P_1$ ) and the second for the unreacted monomer ( $E_1$ ). The monomer feed in the reactor ( $M_3$ ) is the sum of the monomer input in the direct feed ( $M_1$ ) with the unreacted monomer ( $M_2$ ) that returns to the process.

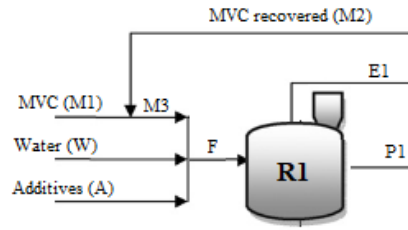


Figure 25. Representation of the polymerization reactor in a block diagram.

Source: Adapted from Tacidelli (2009).

Therefore, making the relations between mass balance for the reactor (Figure 25) considering that there are no significant losses of mass in the polymerization, we have:

$$\text{Input} = \text{output}$$

$$F = E_1 + P_1$$

$$M_3 + W + A = E_1 + P_1$$

$$\text{being that } E_1 = R_1 \times 0.15 \text{ e } P_1 = R_1 \times 0.85$$

$$M_3 = (M_1 + 0.98 \times M_2)$$

$$M_2 = E_1 + E_2$$

$E_2$  being the unreacted monomer removed from the Stripper (3%)

Therefore, based on the equations and values proposed by Tables 3 and 4, Table 6 will show the input and output values of the reactor.

It is important to mention refers to an 8-hour process, therefore, as it is intended to produce 2,424.0 kg of polymer per day, for each complete process, considering the 4 reactors, it is intended to produce 808.8 kg in the total. That is, for each pair of reactors, the total production value will be 404.4 kg.

**Table 6.** General mass balance for production of 8 poly (vinyl chloride)

<b>Mass balance – Reactor</b>			
	<b>Input</b>		<b>Output</b>
	Feeding of raw material (F)	Leaving the product (P <sub>1</sub> )	Leaving the unreacted monomer (E <sub>1</sub> )
Water (W)	484.84 L	484.84 L	-
Monomer (M <sub>3</sub> )	404.4 kg	12.13 kg	60.66 kg
Additives (A)	1.05 kg	-	-
PVC (P <sub>1</sub> )	-	332.66 kg	-
Subtotal	890.29 kg	<b>829.63 kg</b>	60.66 kg
<b>Total</b>	890.29 kg	<b>890.29 kg</b>	

Source: Own elaboration

The input values (water and additives) are taken from the values in Table 1. The water will correspond to 120% and the additives will correspond to 0.26% of the base value of monomer used. However, with the consideration that there was a separation of the system in pairs of reactors, the total volume of water, monomer and additives that would be used to supply the proposed demand for each 8 hours of production is expressed in half in Table 6 and consequently in the others .

Table 7 describes the basic design of the reactors.

**Table 7.** Reactor sizing for polymerization.

<b>Sizing polymerization reactor</b>	
Reactor reactor volume	50 m <sup>3</sup>
Diameter	3.6 m
Height	7.5 m
Number of reactors	4
Amount of water (per reactor)	242.42 L
Amount of additives (per reactor)	0.525 kg
Amount of monomer (per reactor)	202.2 kg/ batch
Amount of unreacted monomer (per reactor)	30.33 kg/ batch
Amount of PVC produced by reactor (with 3% monomer)	171.87 kg/ batch
<b>Reaction medium (by reactor)</b>	<b>445.145 kg</b>

Source: Adapted from Hamilton (2013).

According to Bohnet (2003), there are three options for reactor sizes that are commonly used in the polymerization process: 25 m<sup>3</sup>, 50 m<sup>3</sup> e 75 m<sup>3</sup>. Braskem's poly (vinyl chloride) plants, according to official data, use the 75 m<sup>3</sup> reactors due to the high production of their plants (Braskem S.A., 2021).

Therefore, to meet production expectations, 4 tanks of 50m<sup>3</sup> will be used, taking into account that it is expected that only 2/3 of the total volume will be filled in order to have a margin of error and safety during the process.

#### 4.1.2.2. Report of calculations for suspension tank (T<sub>1</sub>)

Since it has only one inlet and one outlet, all the mixture that enters the tank, represented by Figure 26, after polymerization will also come out. Its main function is to store the product that has just left the polymerization, acting as a space for the decantation of the formed sludge. After decanting, the product will be sent to the stripper.



Figure 26. Representation of the suspension tank in block diagram.

Source: Adapted from Tacidelli (2009).

Table 8 refers to the dimensioning of the suspension tank that will be used at BiPlastic to store the product.

Table 8. Sizing the suspension tank

Sizing the suspension tank	
Maximum volume allowed in the tank	40 m <sup>3</sup>
Tank volume	70 m <sup>3</sup>
Diameter	3.92 m
Height	9 m

Source: Adapted from Hamilton (2013).

With the application of the scale of operation of the equipment, it is possible that only one suspension tank is used for the entire process, in addition to decreasing the total volume of the necessary equipment, thus decreasing the total value of the equipment used.

The entire volume that leaves P<sub>1</sub> will be deposited in the tank, with a residence time of 1 hour so that the product can decant and then be sent to the next equipment.

#### 4.1.2.3. Calculation Report for Strippers (S<sub>1</sub>)

The sludge that comes out of the suspension tank is preheated and directed to the stripper entering the top of the equipment's turret, as shown in Figure 27. The steam will enter the bottom and carry the excess MVC that is still with it in the mud. According to Allen and Baker (2003) previously cited in section 3.3.3., In order to have the best performance of the process, in addition to not degrading the newly formed product, the temperature of the vapors inside it must be between 92 to 132°C.

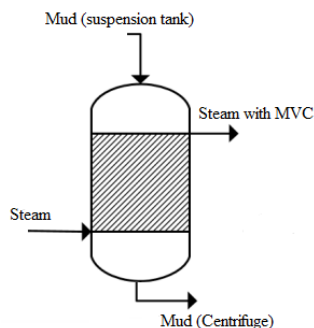
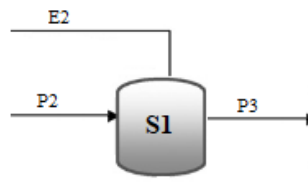


Figure 27. Stripper representation.

Source: Adapted from Tacidelli (2009).

The main function of steam in the system is to perform the separation between the residual monomer and the PVC resin that will enter counter-current, in relation to the injected sludge in the system, in a proportion of 1/4 of the total mass of product injected in the equipment.

From Figure 28, the mass balance for the equipment will be exposed, as well as its values and dimensioning, exposed by Table 9 and Table 10, respectively.



**Figure 28.** Stripper representation by block diagram.

Source: Adapted from Tacidelli (2009).

$$P_2 = P_3 + E_2$$

$$E_2 = 0.03 \times P_2$$

$$P_3 = 0.97 \times P_2$$

**Table 9.** Mass Balance Stripper

Mass balance – Stripper			
	Input	Output	
	Input (P <sub>2</sub> )	Product output (P <sub>3</sub> )	Exit of unreacted monomer (E <sub>2</sub> )
Water	484.84 L	484.84 (±20) L	-
Remaining monomer	-	-	9.98 kg
PVC	332.66 kg	322.68 kg	-
Subtotal	817.5 kg	<b>807.52 (±20) kg</b>	9.98 kg
<b>Total</b>	817.5 kg	<b>817.5 (±20) kg</b>	

Source: Own elaboration.

**Table 10.** Stripper sizing

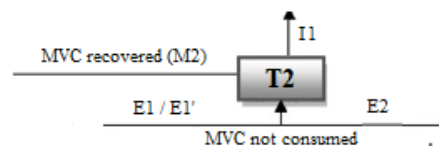
Sizing – Stripper	
Steam / feed ratio	0.25 kg steam / 1 kg mud
Total input mass	817.5 kg
Steam flow	64.05 kg/h
Diameter	1.5 m
Height	9 m
Plates	32
Heat	110 °C
Pressure	1.41 atm
Bottom density (product)	1.16658 kg/L
Top density (steam + MVC)	0.00098 kg/L
Output flow	253.0 kg/h

Source: Adapted from Hamilton (2013).

It is worth mentioning that the input volume of the stripper, corresponding to the volume of two reactors due to the relay scheme adopted. The water volume of the outlet was added  $\pm 20$  L due to the possible pooling that can occur with the steam used in the stripper with the water that is in conjunction with the PVC resin.

#### 4.1.2.4. Calculation Report for storage tank (T<sub>2</sub>)

The T<sub>2</sub> storage tank receives the percentages of unreacted monomer that leave the reactor and the stripper as shown in Figure 29.



**Figure 29.** Representation of the storage tank in block diagram.

Source: Adapted from Tacidelli (2009).

The unreacted monomer returns to the monomer feed inlet at a 98% content. The remaining 2% is attributed to possible impurities.

$$Input = Output$$

$$E_1 + E_2 = T_2$$

$$E_1 + E_2 = M_2 + I_1$$

$$\text{being that } E_1 = 0.15 \times M_3$$

$$E_2 = 0.03 \times \text{Polymer mass in the reactor}$$

$$M_2 = 0.98 \times T_2$$

According to the values found for  $E_1 = 60.66$  kg and  $E_2 = 9.98$  kg, we can identify that the values for the monomer load that returns to the feed is  $M_2 = 69.22$  kg and impurities  $I = 1.41$  kg.

From the value of  $M_2$  and the established value that will enter the monomer in the reactor ( $M_3$ ) it is possible to determine the necessary amount of external monomer that must be fed to the reactor.

$$M_3 = M_1 + M_2$$

$$M_3 = 404.4 \text{ kg}$$

$$M_2 = 69.22 \text{ kg}$$

$$\text{so, } M_1 = 335.18 \text{ kg}$$

Therefore, in relation to the addition of external monomer, for each polymerization (considering the pair of reactors) it is necessary that your feed is 335.18 kg from the second reaction. The first reaction that each reactor pair performs, after a possible stop for review or other needs to stop production, it must be fed by 404.4 kg of monomer considering the absence of the volume that would return to the process through the  $T_2$  process.

Regarding the dimensioning, the storage tank will have the same dimension as the suspension tank (T<sub>1</sub>) presented in section 4.1.2.2.

#### 4.1.2.5. Calculation Report for centrifuge (C<sub>1</sub>)

The main function of the centrifuge is to eliminate the excess water that is found together with the PVC sludge. As it has passed through the stripper, it is expected that the product entering P<sub>3</sub> will contain the regular amount of monomer, with no further process necessary to eliminate it. Figure 30 represents the centrifuge indicating its entrances and exits.

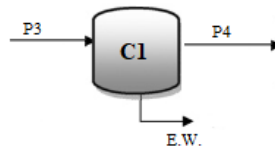


Figure 30. Representation of the centrifuge in block diagram.

Source: Adapted from Tacidelli (2009).

The centrifuge is fed by the P<sub>3</sub> line, which contains a total of 807.52 (±20) kg of mud. Within this total, there are approximately 484.84 (±20) L of water ( $P_{3(water)}$ ). As described by Rodolfo Jr. et al. (2006) and mentioned in section 3.3.3., The centrifuge separates about 80% of the water contained in the sludge, which leaves the system through E.W.

The rest of the mass that contains the PVC resin together with the remaining water that is found in the pores of the polymer follows the process through P<sub>4</sub> towards the dryer. Below are the expressions of the mass balance. Table 11 refers to the balance sheet values and Table 12 to the equipment's technical data sheet.

$$E.W. = 0.8 \times P_{3(water)}$$

$$P_4 = P_3 - E.W.$$

**Table 11.** Mass balance for centrifuge

<b>Mass balance - Stripper</b>			
	Input		Output
	Input (P <sub>3</sub> )	<b>Product output (P<sub>4</sub>)</b>	Water withdrawn from the product (E.W.)
Water	484.84 L	96.97 L	387.87 (±20) L
PVC	322.68 kg	322.68 kg	-
Subtotal	807.52 kg	<b>419.65 kg</b>	387.87 (±20) kg
Total	807.52 kg		<b>807.52 kg</b>

Source: Own elaboration

**Table 12.** Centrifugal technical sheet

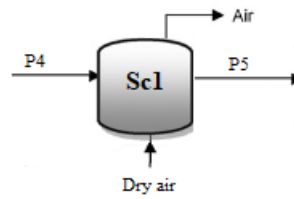
<b>Sizing - Centrifuge</b>	
Total input volume	807.52 kg
Input flow	201.8 kg/h
Humidity output product	20 %
Liquid retention by the centrifuge	480 (±20) L
Output flow (product)	104.9 kg/h

Source: Own elaboration.

The input load and the output load are the values of the inputs and outputs of each equipment in relation to the total batch time that will be happening, that is, as every four hours the entire volume of the reactor goes to the storage tank and it is released to the stripper, the process becomes continuous in all other equipment, all processes occurring simultaneously.

#### **4.1.2.6. Calculation Report for dryer (Sc<sub>1</sub>)**

The function of the dryer, shown in Figure 31, is to remove the rest of the water present in the system, which, in its majority, are in the pores of the polymers through the action against a dry air flow. Due to the high efficiency, fluidized bed dryers are used which, with the collisions between the polymers with the air and the dryer walls, release the remaining water and moisture. Thus, it is expected that the P<sub>5</sub> outlet will be composed only of dry PVC resin.



**Figure 31.** Representation of the dryer in block diagram.

Source: Adapted from Tacidelli (2009).

Table 13 concerns the mass balance. In its construction, it will be considered that the dry air inlet will have a total mass of 20% more than the incoming mass of PVC resin. Regarding the output, it is estimated that there may still be around 1% of the water mass in the dry PVC, which is a safety estimate. Table 14 shows the technical data sheet of the equipment, considering that a fluidized bed dryer will be used.

**Table 13.** Mass Balance Dryer

Mass Balance – Dryer				
	Input		Output	
	Input (P <sub>4</sub> )	Dry air	Product output (P <sub>5</sub> )	output air (+ water)
Water	96.97 L	-	0.9697 kg	96.00 kg
PVC	322.68 kg	-	322.68 kg	-
Air	-	387.21 kg	-	387.21 kg
Subtotal	419.65 kg	387.21 kg	<b>323.65 kg</b>	483.21 kg
<b>Total</b>	806.86 kg		<b>806.86 kg</b>	

Source: Own elaboration

Table 14 shows the dimension of the equipment, considering that a fluidized bed dryer will be used.

Sizing - Fluidized bed dryer	
Air inlet flow	193.6 kg/h
Inlet flow (PVC + water)	209.82 kg/h
Humidity output product	1 %
Air Heat	50 - 60 °C
Operating speed	24.3 m/s
Total column height	3.8 m

Source: Adapted from Brooker, Bakker-Arkema and Hall (1974) and Hamilton (2013).

The dryer reference that was used for its design was the "batch" type, which is one of the cheapest on the market. The height of the dryer was considered the reference described by Brooker et al. (1974) as well as the time and volume of the material that will feed it. Exit P<sub>5</sub> is expected to contain only the MVC resin with no moisture inside. However, by estimate, it will be considered that there will be 1% of the water mass present at the exit P<sub>5</sub>.

#### 4.1.2.7. Calculation Report for sieve (B<sub>1</sub>)

The sieve is the last piece of equipment that makes up the PVC resin production process. With the function of removing malformed granules, agglomerates or possible impurities, the entrance P<sub>5</sub> will enter through the upper entrance of the equipment and will exit at the exit P<sub>6</sub> through an exit in the lower, being that, all the other globules will exit through the exit I<sub>2</sub>, as it is possible observe in Figure 32.

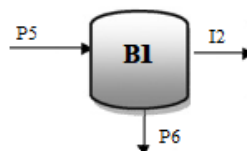


Figure 32. Representation of the sieve in block diagram.

Source: Adapted from Tacidelli (2009).

It will be estimated that about 1% of the total PVC formed will come out by I<sub>2</sub>, considering also possible losses due to accumulation inside the equipment. Table 14 refers to the mass balance, indicating as a result the final quantity that will be produced by the entire system.

**Table 14.** Sieve mass balance.

<b>Mass balance – Sieve</b>			
	Input	Output	
	Input (P <sub>5</sub> )	<b>Product output (P<sub>6</sub>)</b>	Impurities (I <sub>2</sub> )
PVC	323.65 kg	<b>320.41 kg</b>	3.2365 kg
<b>Total</b>	323.65 kg	<b>323.65 kg</b>	

Source: Own elaboration

The sieve that will be used will not be designed, therefore, in the section operational plan there will be more details of which equipment will be purchased, considering its function in the polymeric area.

#### **4.1.2.8. General mass balance**

Therefore, after carrying out the mass balance for the main equipment that govern the recovery of the monomer and the reduced PVC production line, the general balance that should be made for production considering each pair of reactors will be presented in Table 15. Table 16 will show the mass balance for daily production. It is interesting to note that, due to the organization that was proposed for production, productions will be made by pairs of reactors (R<sub>1</sub> e R<sub>1</sub>') where they will work at intervals of 4/4 hours three times a day to complete 3 batches.

**Table 15.** Mass balance for reactor pairs R<sub>1</sub> e R<sub>1</sub>'

General mass balance for each double reactor - BiPlastic					
Input/output (kg)		Input/output (kg)		Input/output (kg)	
M <sub>1</sub>	335.18	E <sub>1</sub>	60.66	Air (+water)	483.21
M <sub>2</sub>	69.22	E <sub>2</sub>	9.98	P <sub>1</sub>	829.63
M <sub>3</sub>	404.4	I <sub>1</sub>	1.41	P <sub>2</sub>	817.5
W	484.84	I <sub>2</sub>	3.2385	P <sub>3</sub>	807.52 (±20)
A	1.05	E.W.	387.87 (±20)	P <sub>4</sub>	419.65
F	890.29	Dry air	387.65	P <sub>5</sub>	323.65
<b>P6 (Final Production) = 320.41 kg</b>					

Source: Own elaboration

**Table 16.** Daily mass balance of production.

Daily mass balance- BiPlastic					
Input/output (kg)		Input/output (kg)		Input/output (kg)	
M <sub>1</sub>	2,011.08	E <sub>1</sub>	363.96	Air (+water)	2,899.26
M <sub>2</sub>	415.32	E <sub>2</sub>	59.88	P <sub>1</sub>	4,977.78
M <sub>3</sub>	2,426.4	I <sub>1</sub>	8.46	P <sub>2</sub>	4,905.0
W	2,909.04	I <sub>2</sub>	19.43	P <sub>3</sub>	4,845.12 (±20)
A	6.3	E.W.	2,327.22 (±20)	P <sub>4</sub>	2,517.9
F	5,341.74	Dry air	2,325.9	P <sub>5</sub>	1,941.9
<b>P6 (Final production per day) = 1,922.46 kg</b>					

Source: Own elaboration

Therefore, from these results, it can be concluded that, if the proposed considerations for the start of production are carried out, the annual goal will be achieved. Therefore, considering the daily production of PVC resin being 1,922.46 kg per day and the production will work continuously for 330 days (considering maintenance stops or possible problems in the line), the annual production of biopolymer that BiPlastic will be of 634,411.8 kg.

Therefore, starting from 800,000 kg of monomer, together with the other raw materials involved in the reaction, 634,411.8 kg of PVC resin is produced. This percentage value shows that the process would have approximately 80% yield, 5% below expectations. Based on this data and such considerations made during the process, it is possible to consider that, using 1,000,000 kg of

monomer, there will be an average conversion of 800,000 kg of PVC resin, this value being used to perform the calculations of the financial analysis, as it is related to the company's expected annual production.

#### **4.1.3. Preliminary treatment of effluents**

As was explained by the general production, there is no generation of unwanted by-products in the production of the polymer considering that the process starts with the polymerization of the monomer coming from previously ready natural and renewable sources. The MVC, as already exposed, is extremely harmful to humans, being toxic and carcinogenic, therefore, its presence must be controlled in the final product and also during the entire process including in the presence of possible effluents or residues.

The recovery initially proposed by BiPlastic is that, at the outputs of the reactors and the stripper, there will be the monomer recovery system, in the gaseous state, where after leaving the equipment it will pass through a filter that will be installed in the pipes, in order to prevent other residues follow the gas that will go to the T<sub>2</sub> reservoir, where the gas will be condensed and returned to the process. A safety margin of 2% is placed on this equipment in case of the occurrence of impurities, water droplets, etc. A new filter will be implemented in the piping that will be sent to the feed, since, as the monomer will return as a gas, the remaining impurities were left in the tank leaving the outlet I<sub>1</sub>. The I<sub>2</sub> exit of the sieve should be incinerated, as suggested by De Campos and Seo (2009).

For the water used in the process, a refueling and recycling scheme will be implemented. It is intended to install an ultrafiltration ceramic membrane where the water that is removed from the centrifuge may return to the process being used either in the reactor heating jacket or in the tank's refilling. The expected percentage of reuse must be considered the loss that may occur in the dryer and in the centrifuge itself, with the percentage of water that is removed together with the air.

Despite the existence of a treatment and recycling of the water used in the project, at the moment the value of its percentage will not be estimated due to other factors being involved in such a process, such as the necessary energy and the equation of such equipment itself, however.

value will be within the total estimated cost for the project. Therefore, in principle, the total mass of water that was indicated in Table 4 will remain the same.

Regarding the treatment of the air outlet in the Sc1 dryer, it will go through a cyclone to avoid the presence of any other residue and will be released for atmospheric exposure. At this stage of the process, the presence of MVC is disregarded, but daily analyzes should be carried out on collectors to understand the status of the process and to prepare for any mismatch in its limit rate.

All explanations within this section should be reviewed during the process, to always evaluate the best yield that brings financial benefits and mainly from non-pollution and the safety of the environment and the workers who will be around the company.

## **5. Business plan**

The proposal presented by this work is to develop a business plan for a company focused on the production of green poly(vinyl chloride), replacing oil as a source of raw material with sugar cane, together with the recovery of residual vinyl chloride monomer from the process.

Therefore, this session will present all the steps and developments necessary for the construction of the business plan of the fictional company BiPlastic, being used as the basis for its construction the IAPMEI, Agency for Competitiveness and Innovation in Portugal.

### **5.1. Methodological aspects**

As pointed out by Serviço Brasileiro de Apoio às Micro e Pequenas Empresas (2016) one of the main factors of high mortality rate of the companies is the lack of business planning, being pointed out that, between 2010 to 2014, the survival rate of companies that previously carried out a business plan rose from 54 to 77%. Therefore, from the operational planning shown above, the need to carry out and execute a detailed business plan is of paramount importance for its vitality in the market.

Building the business plan for the future investment with economic engineering as the basis for the initial phases of this enables, achieves and matures the business project, evaluating its possible financial return and thus verifying whether or not this will be a profitable project. Although, in the initial phases, it is not possible to determine the exact cost of execution, and consequently the expenses and gains, it is possible to make estimates of expenses, and from these, verify the feasibility of the project (IAPMEI, 2016; Primo et al., 2017).

This feasibility can be realized from an economic analysis, and when carried out in a chemical plant, a series of factors must be taken into account in order to be able to assess whether the investment and risk provided by it will be worth it in financial terms. Parameters such as investment, income, cost and profitability are the main points for such an evaluation, the latter of which must be analyzed in the comparison of profits from the sale of products in contrast to the

initial investment and all operating costs that include infrastructure, raw materials used and labor involved (Primo et al., 2017).

The business plan must focus on the main points of the project, defining and organizing all the resources to be used to materialize the idea that is intended to be implemented when building the fictitious company in the field of polymers. According to IAPMEI (2016) the business plan must contain a summary, objective, identification of the key factors of the project and market and financial analysis that supports the idea of the same.

From its construction it is possible to identify if there is a need for a product and if the problem to be solved with the new enterprise has space in the current market. Thus, identifying such needs and consumer preferences, the enterprise will be shaped and creating more foundation (IAPMEI, 2016).

The following is a brief explanation of the basic structure, according to IAPMEI (2016) of the business plan that will be developed during this work:

- **Executive summary:** It aims to expose the company's business plan, showing the competencies, intended objectives and financial perspectives of the business. A simple analysis of the market to which the enterprise will be inserted, resources to be used and the deadlines for profit must be indicated in the document (IAPMEI, 2016).
- **History of ideas and / or promoters:** The main objective is to explain about the creation of the project and its reasons. It must tell the business's mission along with its purposes and goals (IAPMEI, 2016).
- **Operational plan:** Objective to describe the entire production process, indicating the stakeholders, raw materials and the planning of supply and delivery of the entire product for the good functioning of the company (IAPMEI, 2016).
- **Market analysis:** To define the market in which the company will be inserted, indicating its size, level of development, types of customers to be reached and competitors. Within it, some sections should be pointed out as: Underlying market, the analysis of the sector (with the objective of analyzing with a brief history the market in which the project will be introducing itself to evaluate the sector's trends) and the market positioning present the

business, presenting the product, the physical and production resources that will be required as well as the management capacity (IAPMEI, 2016).

- **Financial evaluation:** Objective to indicate the projection of sales, payments, and profitability. In general, all expenses and returns that the product will generate for the company (IAPMEI, 2016).
- **Strategic evaluation:** Objective to present plans and forecasts for the company over the years (IAPMEI, 2016).

As explained by Kuhn and Dama (2009), the financial plan is the final part of the business plan, indicating whether the project will be viable or not. It must contain how resources will be obtained, the source of investments, projected costs and revenues for each period and the construction of cash flow.

Therefore, with the presented methodology, the data, and directions that BiPlastic will take in order to reach its objectives will be exposed in the next sections.

## **5.2. Executive summary**

BiPlastic will be a company that will operate in the industrial sector focused on the production of green polymers through the transformation of vinyl chloride monomer from non-fossil raw materials into poly(vinyl chloride). It will dedicate to serving molding companies that use PVC resin as a raw material, ranging from food industries to automobiles.

The increase in the search for research and production that generates processes and products that do not harm the environment has made BiPlastic propose to establish itself as a PVC production company that does not use fossil sources in its matrix, making it with a structured green cycle with high environmental responsibility. Using sugar cane as the basis for its production, the company proposes as its main commitment the quality of the product combined with care and responsibility to the environment.

Therefore, BiPlastic's objective, together with the company's vision and mission, is to become the main producer of green PVC resin in Portugal, aligned with innovation and new

technologies, seeking quality in its process and especially the commitment to the environment. . The company's brand as well as its logo is shown in Figure 33.



**Figure 33.** Company logo.

Source: Own elaboration

Standing out for having and using the green process as its main marketing, the company will benefit in marketing issues by searching for new consumers in brands that use resources that do not negatively affect the environment. This strategy is linked to the non-use of fossil sources, a finite resource explored and used in the area in question and the use of sugarcane, which results in marketing that relates the contribution to the carbon cycle generated and consumed until purchase and helps raw material producers.

The company will be headquartered in Aveiro, Portugal, due to its geographic location to facilitate access to raw materials, as well as being one of the country's industrial hubs and for having a port, which facilitates the transportation and acquisition of raw materials. When taking into consideration the type of market, the company will work with the B2B (business to business) relationship, that is, sales of companies to other companies, not having direct contact with final consumers, but selling to companies that transform the BiPlastic product in it.

With the production of green PVC, it is intended to meet the demands of European companies in relation to the product sold by BiPlastic. Such demand can be premeditated thanks to the new investments that companies already consolidated in the sector are looking for, in order to serve new customers and adapt in relation to the new environmental laws and the own consumption of finite resources. It is known that, currently, Braskem is investing in technology

and development of biopolymers, but with no forecast for European expansion in the short term, but with a predicted deadline for 2050 (Braskem S.A., 2021).

Therefore, BiPlastic's goal is to enshrine the brand starting in the region of Portugal and expanding its market to Europe, becoming the reference in the market in which it is intended to be installed.

### **5.2.1. History of ideas and / or promoters**

The BiPlastic creation project appears to align the expectations of a new generation of consumers concerned with the trajectory that their consumer goods cross until they reach you and the impacts they cause with the environment, with the innovation and creation of a company with green processes that aims to minimize any type of aggression that this can cause in the environment. With a process entirely molded in the green cycle, BiPlastic, in addition to using the monomer from renewable sources, intends to assist small and medium producers, with direct trade with fair remuneration for their work to stakeholders who have the same ideal in relation to the means of production.

Regarding production, the company's main goal is to cover the entire process involved in the production of green polymers, obtaining the raw material, producing ethanol and transforming it into ethylene and vinyl chloride monomer and distributing the polymer in European territory. However, to achieve this goal, three internal steps will be imposed for BiPlastic to achieve that goal. The first is the initial installation of the transformation process of the finished monomer into PVC resin, as suggested and to which this work is suitable. BiPlastic will buy the monomer from third parties who, in turn, also bought the sugar cane from third parties. At this time, BiPlastic's follow-up will only be to observe how the processes of outsourced companies are and to ensure that such companies are in accordance with the company's sustainability and environmental protection policy.

The second step is the construction of a unit for transforming sugar cane into ethylene, a raw material necessary to produce monomer. With the construction of this system, the production itself will be fully owned by BiPlastic, being possible to control the entire process according to the company's mission.

The third step is in relation to stakeholders and the entire environment in which the company operates. It is intended, after carrying out the two steps, to make BiPlastic interact with the entire market in which it reaches indirectly to make the entire product cycle as sustainable as possible.

### 5.2.2. Strategic vision and business mission

BiPlastic's vision is based on three solid bases that guide the whole idea of the company's process, namely: the commitment to sustainability, environmental responsibility in all areas of activity of the company and the guarantee of the quality of its products, being these the values that will guide all the processes and actions taken by the company, as can be seen in Figure 34.



Figure 34. BiPlastic strategic vision.

Source: Own elaboration

BiPlastic's mission, as previously mentioned, is to produce quality green PVC resin ensuring environmental responsibility throughout its chain. The company's mission and vision will guide the three processes that the company intends to achieve, these being totally connected with the production and green policies that the company defends and applies.

### **5.3. Operational plan**

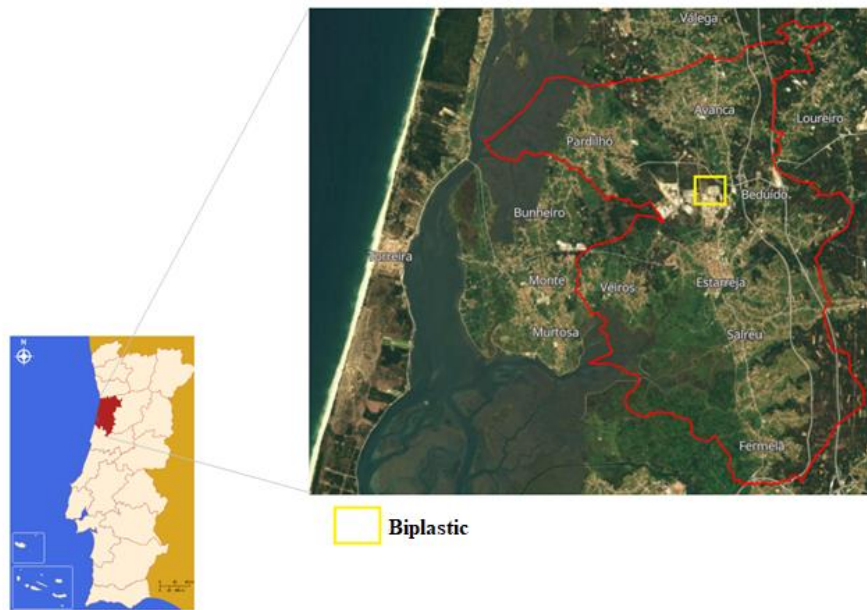
BiPlastic intends to produce PVC bio resins from vinyl chloride monomer from natural sources, acquiring the raw material of the process, at first, through trade with third-party companies. It is intended, after installation of the company with the necessary machinery, that the factory has an annual production, considering 330 days, of 800,000 kg of bio resin. The remaining days of the months will be disregarded in the account in terms of expectations of eventual production stoppages.

As shown, production will start with a reduced process, in relation to other companies in the sector, mainly due to the high cost of opening a large company and because it is initially working only with a type of resin.

To elaborate the operational plan, some points will be explained, being the location and as the company's intended facilities, the necessary equipment as well as a preview of the workforce and its organization, the project's operational costs and the critical points of the project.

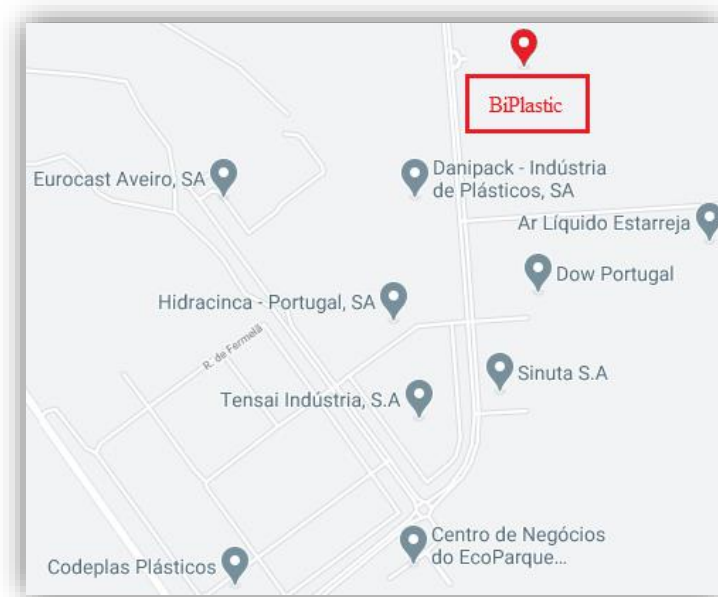
#### **5.3.1. Location**

It is intended to build BiPlastic in the parish of Avanca, council of Estarreja, in the district of Aveiro in Portugal. Such a location is strategic as it is known as the Estarreja Chemical Complex (CQE), located 20km from the capital of the district and approximately 30km from the sea. Figure 35 demonstrates the top view used by Google Earth (2021). Figure 36 shows the companies that are part of the Estarreja Chemical Complex (CQE) and will be close to the place where BiPlastic is to be installed.



**Figure 35.** Top view of BiPlastic's location.

Source: adapted from Google Earth Maps (2021).



**Figure 36.** Location of the Estarreja Chemical Complex with the location of BiPlastic.

Source: Adapted from Google Earth Maps (2021).

This choice is based on three main points: The first is the proximity of large companies such as CUF, Air Liquide, CIRES, Dow Portugal, Codeplas Plásticos and Danipack, companies

that BiPlastic aims to maintain a relationship of trade in its resin and purchase of products when needed.

The second is in relation to the benefits that the place receives from the government due to the large generation of income resulting from the production of such companies. According to TerraNova (2018), the Minister of Economy outlined plans to reduce the collection of resources, such as electricity from the area.

The third is related to the strategic point in relation to marketing. As BiPlastic will be a new company, when participating in a complex of companies that has a weight in their names with brand and prestige already established in the community, it is expected that, with the approach, organic marketing will occur in relation to the company.

### **5.3.2. Installations**

BiPlastic's facilities will consist of two base units, one for the production and administrative headquarters, which will be installed in the same location and one located in the Port of Aveiro, which will be rented periodically according to the need for raw material reception. This second space will be concomitant with the space used by the company CIRES, which maintains in this port its own space for receiving its own raw materials.

Regarding the production facility and administrative headquarters, Figure 37 represents its layout, adapted to the reality of BiPlastic.

According to data provided by the CIRES operational report (2017), the company's industrial area is approximately 13.5 hectares for its industrial area and 28.2 hectares as the total area. Its annual production, in relation to the year in question, was 215,000 tons, with two different types of processes (suspension and emulsion) for the formation of its final products. Therefore, the initial area will be based on the area used by the CIRES company.

Considering that the BiPlastic process is presented in a reduced model with the minimum of equipment necessary for its operation, having only one production line (suspension polymerization) with a single product to be modeled, the physical area allowed for its production will be 3 hectares with a total area of 7 hectares considering the administrative headquarters and other needs of the company (reduction of 75% of the amounts presented by CIRES). Despite being

an initial estimate, the amount of the reduction was also due to the quantity of equipment and production volume of CIRES, which are also shown in the same report.

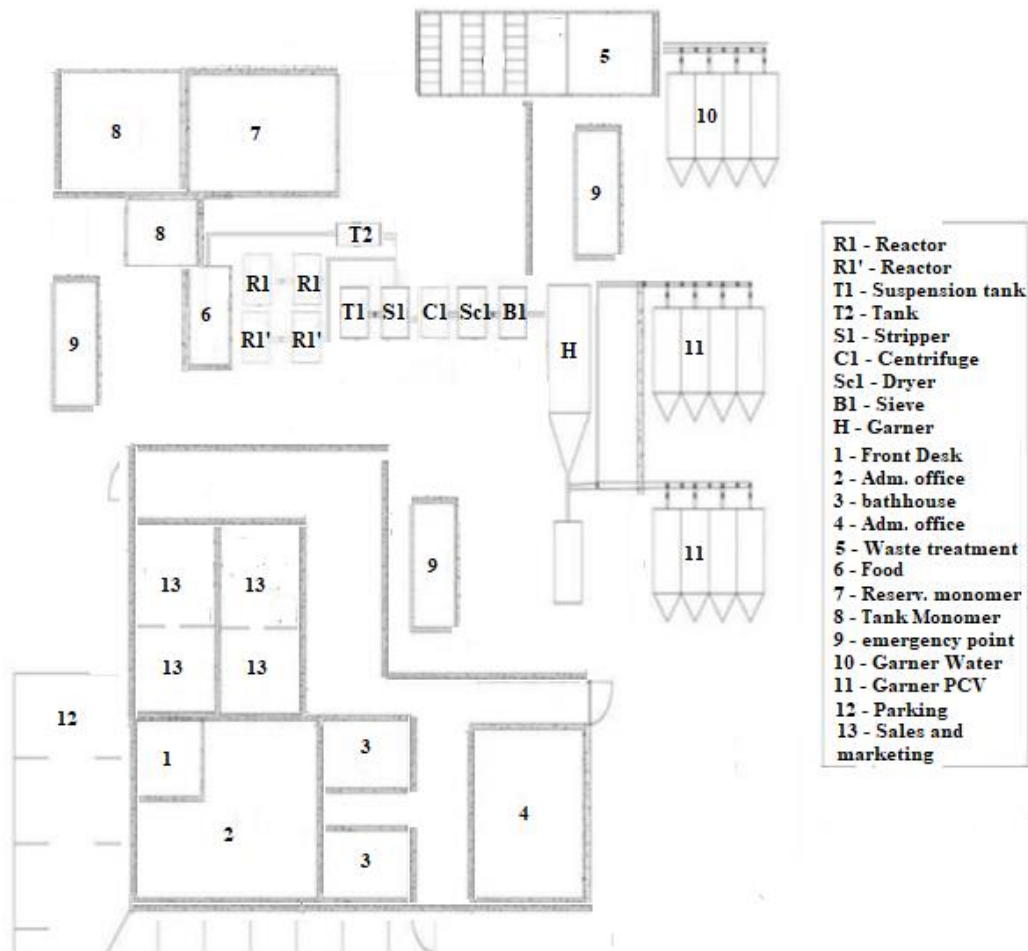


Figure 37. Layout layout of BiPlastic.

Source: Adapted from Peters et al. (2003).

It is expected that the environment will be and present itself with an organized, clean and woody aspect for a good presentation, which will be favored by the installation and maintenance of green spaces around the company.

### 5.3.3. Organization chart and manpower

BiPlastic's organizational chart is shown in Figure 38, composed of the company's general manager and the four main sub-areas: communication (this being made up of sales and marketing), operation, administration, and people management (HR).

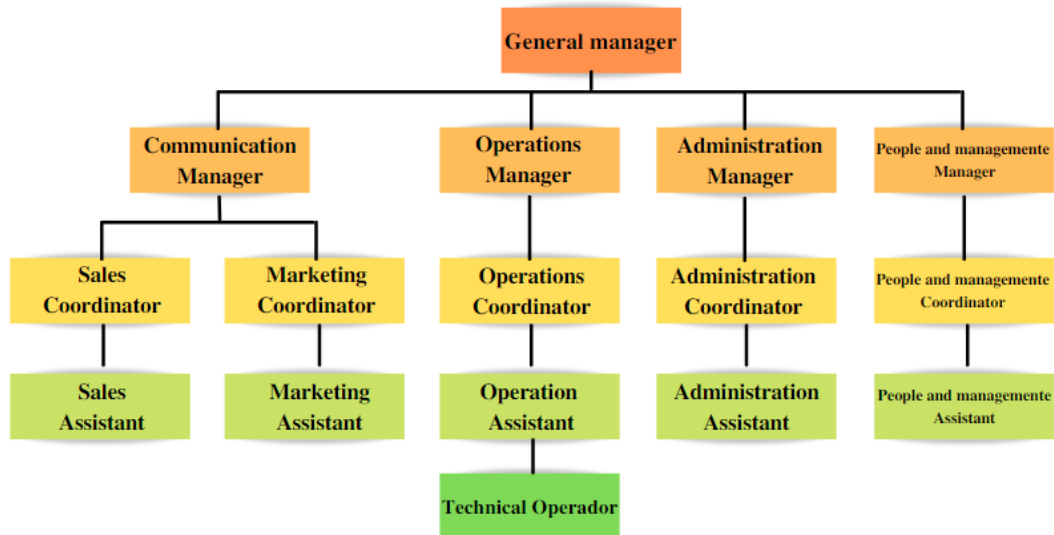


Figure 38. BiPlastic organization chart.

Source: Own elaboration

With well-defined positions, each area will have unique responsibilities but that will follow the company's internal and external demands. Communication will be responsible for marketing the product and selling the product with the accompaniment of customers with during and after sales. Operations will be responsible for monitoring the production process. The administration will take care of external financing, revenues and payments and receipts. The people and management will take care of the internal part, as well as the monitoring of workers and occasional situations within the company. The general management of the company will have the responsibility to monitor the entire situation of the company with the general and panoramic view of all sectors.

With the front and back office defined, the next section will be calculated the costs of the labor involved.

### 5.3.3.1. Estimation of Labor cost

As pointed out by Seider et al. (2009) and Turton et al. (2009), to determine the cost of labor, the wages and direct benefits of workers must be considered the environment in which they find themselves, in this case, within a chemical plant operation.

The method that will be adopted for the previous determination of the wages of the workers will be to forecast the cost with the labor specialized in the process (therefore the operations workers) and from such expenses, when predicting by the Lang method the operational costs, the other expenses with the wages of other workers will already be included in the total amount found. As already mentioned, this method is accepted for chemical plant operations and it is for this reason that its use is directly related to the workers of the process itself.

The cost of labor is called DW&B (direct wages & benefits), and, for its determination, Equation 7 will be used:

$$DW\&P = N_{OP} \times (\text{work shift}) \times \text{amount of hours} \left( \frac{h}{\text{year. operator}} \right) \times \text{salary} \left( \frac{\$}{h} \right)$$

Equation 7

Therefore, that: DW&P refers to direct dollars and benefits in dollars and  $N_{OP}$  is the number of operators per shift, determined by equation. Points that have already been replaced in the formula are the total number of shifts worked during the week (3 shifts), the number of hours the worker will work during the year, which is 2,080 h / year. Regarding the base salary, the amount indicated by Seider et al. (2009), for workers in chemical plants is \$25/h.

However, data released by the Labor and Employment Bulletin (2020) indicate that the base salary given to level IV engineering professionals (the highest among the levels) is \$ 8,400.00 dollars per month which would result in approximately \$ 35/h, which will be used to make the estimate. Such a choice was made using the highest position suggested for skilled workers to have a safety margin between the wages of other workers.

The result that will be found by Equation 7 already includes the other expenses that the company has with its workers, such as meals, labor rights, etc. point considered by the author when choosing the hourly price of the worker.

To determine  $N_{OP}$  we will use Equation 8:

$$N_{OP} = (6,29 + 0,23 \times N_{EQ})^{0,5}$$

**Equation 8**

$N_{EQ}$  is the number of equipment that the plant has in the case of BiPlastic, 11 different equipment will be used, considering the final storage silo of the newly produced PVC. The storage tanks that are involved in the process, these being the monomer storage in Porto and pre-production and those for the storage of the final product will have the values included in the final value of the project. The other values of the equations represent constants indicated by Seider et al. (2009).

Therefore, replacing the value of  $N_{EQ}$  in Equation 8, we have that  $N_{OP}$  is equal to 4. Replacing this value in Equation 7, we find that the cost of wages and direct benefits that BiPlastic will have throughout the year with its employees is equal to \$ 873,600.00.

#### **5.3.4. Estimation of equipment costs**

As demonstrated by the calculations and considerations in section 4.1.2, the reduced production line contains approximately ten chemical equipment and storage tanks, disregarding the equipment for treating effluents emitted by the process that will be included in the calculated final price. The equipment that will be used as well as its cost are available in Table 17. As a reference to determine the values that will be presented in the table, they were used as a source of Joint Bioenergy Institute (2011), Seider et al. (2019) and Turton et al. (2009).

**Table 17.** BiPlastic equipment and cost benchmark.

Equipment	Nomenclature	Volume m <sup>3</sup> or flow rate kg/h	Amount	Value
Batch reactor	R <sub>1</sub> e R <sub>1</sub> '	50	4	125,000 USD.
Suspension tank	T <sub>1</sub>	228	1	60,584 USD
Storage tank - reflux	T <sub>2</sub>	228	1	60,584 USD
Stripper	S <sub>1</sub>	25.62	1	150,000 USD
Centrifuge	C <sub>1</sub>	25.3	1	28,385 USD
Dryer	Sc <sub>1</sub>	13.3	1	83,000 USD
Sieve	P <sub>1</sub>	13.3	1	35,000 USD
Silo	H	1,000	1	70,000 USD
Monomer storage tank - Porto	IP <sub>1</sub> , IP <sub>2</sub> , IP <sub>3</sub> e IP <sub>4</sub>	5,000	4	90,500 USD
Monomer storage tank - Company	-	5,000	2	84,870 USD
PVC resin storage tank	-	1,000	8	88,000 USD
<b>Total</b>				<b>2,223,293.0 USD</b>

Source: Adapted from Joint Bioenergy Institute (2011), Seider et al. (2019) and Turton et al. (2009).

Some specifications were assumed in relation to the equipment because it refers to the sources that were used and their due costs are shown in Table 17: All storage tanks were considered to have a conical roof and will be carbon steel. The reactor will be made of batch stainless steel. The centrifuge used will be for discs and the Spray Dryer type dryer, both in stainless steel, as well as all other equipment.

From the total value of the main equipment, it will be possible to assume the estimated capital investment costs using the Lang's Method, shown in section 5.3.7.

### 5.3.5. Estimation of raw material costs

As mentioned in the construction of the Biplastic production line, a larger quantity of raw material will be purchased than will be necessary for production, in order to have a satisfactory safety margin within the company itself. Therefore, approximately 1,000,000 kg of monomer, 1,000 kg of suspending agents and 1,600 kg of initiators will be purchased.

According to data released by the Independent Commodity Intelligence Services (2021), the price of VCM in 2011 from fossil sources was 0.326 USD / kg or 326 dollars per ton. The

same website provides the price of the monomer coming from bio ethanol being 0.479 USD/kg or 479 dollars per ton.

The suspending agent that will be used as the basis for the process and price will be poly (vinyl alcohol), PVA, and the price of its ton was 2,067 dollars in 2020 (Echemi, 2020).

The initiator, which will be used as the basis for the process, will be 2,2'-Azobis (2,4-dimethyl) and the price of its tonne was 1,000 dollars in 2020 (ChemicalBook, 2020).

Table 18 shows the raw material cost estimate used by BiPlastic.

**Table 18.** Estimation of costs of BiPlastic raw materials.

raw material	Amount consumed	Ton cost (dollars)	Total Cost (dollars / year)
Monomer	1,000,000 kg	0.479	479,000.00
Suspension agent	1,000 kg	2.067	2,067.0
Initiators	1,600 kg	1.0	1,600.0
<b>Total</b>			<b>482,667.00</b>

Source: Own elaboration

Considering that the final product will be sold for \$2,897.0 per ton and the annual production is 800,000 kg or 800 tons, the total final income value of the products will be 2,317,600.00.

### 5.3.6. Industrial services/utilities

All services auxiliary to the company's production process are categorized as industrial services or utilities, which is electricity, process water and public water (Peters et al., 2003).

The company's electricity will be supplied through hydroelectric plants located in the Douro effluent dams and in the Cávado Basin, being responsible for providing energy 24 hours for the entire chemical complex in Esterreja. In relation to the other energy sources used by Portugal, in June 2020 it was found that 30% was from natural gas, 25% from wind and 22% from hydropower (Eco, 2020; Pacopar, 2020).

Despite being the eighth country in relation to the price of electricity in the European Union, costing about 0.2154 cents per kWh considering taxes and fees, the Portuguese government provides incentives for new companies in the country, making the value of electricity 85% lower in relation to that paid by normal consumers, falling to 0.038 cents per kWh (Eco, 2020).

Regarding the water used, they are divided between process water and drinking water. The process water will come from collection wells and must have the authorization of the Hydro Resources of Portugal (ARH) in accordance with Law N°. 58/2005. Drinking water, on the other hand, will come from public networks and transported through normal pipes to supply toilets and general services (Peters et al., 2003).

### **5.3.6.1. Estimated utility costs**

Utilities costs must be made considering the amounts spent by the entire plant regarding the number of days on which it will produce. Their costs will be based on reference values provided by Mejdell (1999), Luyben (2011) and Turton et al. (2009) for chemical PVC production plants.

The values for a medium-sized company and the basic amount of electricity charged by Portugal in the specified area will be considered. The amount of water was measured at the value calculated for annual production, being 1,200,000.0 L. Water and electricity costs are shown in Table 19.

**Table 19.** General utilities price, in dollars.

<b>Utilities</b>	<b>Annual consumption</b>	<b>Cost</b>	<b>Total Cost (\$ / year)</b>
Electricity	40,025.90 GJ	10.55 (\$/GJ)	422,495.6
Water	1,200,000.0 L	0.001 (\$/L)	1,200.0
<b>Total</b>			<b>423,695.6</b>

Source: Mejdell (1999), Luyben (2011) and Turton et al. (2009)

### 5.3.7. Estimated investment costs

Capital investment costs include project expenditures for facilities, costs of equipment and services in general (Seider et al., 2009).

As pointed out by Peters et al. (2003), the capital estimate varies according to the level of understanding and development of the project, being able to start from an initial phase with only pretensions to phases with more complex specifications. Therefore, to calculate the investment and capital needed for BiPlastic, the invoiced estimates will be used, as it is based on the main process and preliminary equipment, as it has sufficient data to carry out a budget and build the financial plan.

For this, the Lang's Method will be used, a method used to estimate the cost of capital of a chemical plant based on the nature of the process carried out (Seider et al., 2009).

Therefore, according to the method, Equations 9 and 10 below are used:

$$C_{TPI} = 1,05 \times f_{LTPI} \times \sum \frac{I_i}{I_{b(i)}} \times C_{pbase}$$

Equation 9

$$C_{TCI} = 1,05 \times f_{LTCI} \times \sum \frac{I_i}{I_{b(i)}} \times C_{pbase}$$

Equation 10

Where:  $C_{TPI}$  – Cost of fixed capital investment, dollars;  $C_{TCI}$  – Total capital investment cost, dollars;  $f_{LTPI}$  – Lang's factor for  $C_{TPI}$ ;  $f_{LTCI}$  – Lang's factor for calculating  $C_{TCI}$ ;  $I_i$  – Cost index on the current date;  $I_{b(i)}$  – Cost index in the base year;  $C_{pbase}$  – Base cost of equipment, dollars. Table 20 indicates the tabulated values of the lang factors in relation to the type of chemical plant.

**Table 20.** Lang's factor

Chemical Plant Type	Lang's factor	Langs factor recommended by Peters et al. (2003) without including working capital ( $f_{LTPI}$ )	Langs factor recommended by Peters et al. (2003) with including working capital ( $f_{LTCI}$ )
Solid Process Plant	3.1	3.97	4.67
Solid-Fluid Process Plant	3.63	4.28	5.03
Fluid Processes Plant	4.74	5.04	5.93

Source: Adapted from Seider et al. (2009).

The values of the cost index at the current date,  $I_i$  were obtained by Joint Bioenergy Institute (2011), Seider et al. (2019) and Turton et al. (2009), and each equipment used in the main process corresponds to a value of  $I_i$ . The cost index in the base year,  $I_{b(i)}$  was obtained in relation to the year 2018 by Jenkins (2018). Such values are shown in Table 21.

**Table 21.** Value reference per equipment.

Equipment	quantity	Value ( $C_{pbase}$ )	$I_i$	$I_{b(i)}$
Batch reactor	4	125,000 USD	500	603.1
Suspension tank	1	60,584 USD	500	603.1
Storage tank - reflux	1	60,584 USD	500	603.1
Stripper	1	150,000 USD	500	603.1
Centrifuge	1	28,385 USD	500	603.1
Dryer	1	83,000 USD	500	603.1
Sieve	1	35,000 USD	500	603.1
Storage silo	1	70,000 USD	500	603.1

Source: Joint Bioenergy Institute (2011), Jenkins (2018), Seider et al. (2019) and Turton et al. (2009).

Therefore, replacing in Equations 9 and 10 the values found in Tables 17 and 20, we find the costs of total capital investment,  $C_{TCI}$  dollars and the costs of fixed capital investment,  $C_{TPI}$  in dollars. It is worth mentioning that, in the case of polymer companies, the classification of the plant to be used in the Lang's method is a fluid process. The final values are shown in Table 22.

**Table 22.** Result of investment costs of fixed and total capital in dollars.

Lang's method	Fluid chemical plant	Estimate
$f_{LTPI}$ (fixed)	5.04	$C_{TPI} = 4,337,688.3$ USD
$f_{LTCI}$ (total)	5.93	$C_{TCI} = 5,103,668.97$ USD

Source: Own elaboration

We can include in the Cost of fixed capital investment ( $f_{LTPI}$ ) all assets necessary for the company to be able to carry out its activities, including vehicles, office supplies, production machinery, land, copyrights, brand patents and other workers' salaries. The total capital investment cost, in addition to including fixed capital, also considers raw material stocks, the other equipment that will be included in the process (such as the effluent treatment part and other storage tanks) and other goods that can be invested in profit (Camargo, 2017).

### 5.3.8. Critical points

Critical points of the project have as main vectors the logistics related to the raw material and the sale of the final product.

The raw material for the project will be sugar cane, which depends on factors such as organized logistics so that there are no delays in production in addition to a satisfactory planting/harvest during the year. As the production of monomer as well as its purchase will be outsourced initially, there must be contact and control of the quantity available for purchase, as well as the cost that the raw material will have.

Therefore, having a raw material reception logistics as well as a good system for capturing the port to the company is a crucial factor for the good functioning of the company.

The final product produced by BiPlastic will be a green product that uses renewable sources as a raw material in addition to being part of a process with a positive CO<sub>2</sub> balance aimed at responsibility to the environment in all processes and stakeholders that circulate the same.

However, as it is not a process of origin widely disseminated by large companies, its market value tends to be higher when compared to products of fossil origin widely disseminated in the market. This fact makes the sale and marketing of the final product as a major critical point in the

process. With a reduced initial production, when compared to other polymer resin producing plants, the first step will be to reach a wide range of customers so that the name and brand of the product is widely disseminated. The market analysis will be the section that will ensure that, despite being a critical point in the process, the product has space in the market.

Other critical points, such as the amount of raw material and production time, were already considered during the calculation, and the estimated value of the purchase of the raw material for the process was maximized, but without having unnecessary stocks, and the production time was reduced. considering maintenance stops or other unscheduled events.

As calculated, the total value of the project is 5,103,668.2 USD which includes all costs for equipment and machinery used in the facilities, the physical land, stock and raw material, cost of utilities including water for consumption, water for process, electric energy and pressurized air for equipment, cost of treating effluents, cost of employees, legislation and regulations, depreciation over time and overhead (expenses indirectly related to the operation of the chemical plant such as fire protection and inspection services, transport, first aid and cafeteria) (Seider et al., 2009).

## **5.4. Market analysis**

The main purpose of the market analysis is to assess how the current Portuguese market is for receiving the product that BiPlastic will supply. This section includes the underlying market, the necessary market positioning for the company, the suppliers as well as its customers and competitors and the final product pricing.

### **5.4.1. Underlying Market**

Aligned with the idea of sustainability, large companies today, such as Braskem, have increasingly invested in technology aimed at the production of plastic from sustainable raw materials that harm the environment less. Braskem is the market leader when it comes to thermoplastic resins, with a range of products in addition to its 36 branches spread across Brazil,

the United States and Germany and it is currently the largest producer of biopolymer in the world (Braskem S.A., 2021).

According to news officially linked by the institutional website, in 2021 Braskem is preparing to invest around US\$ 61 million in expansion for the production of bio polymers, expanding its production capacity of green ethylene from sugar cane with the intention of becoming a carbon neutral company by 2050, with a reduction of approximately 185 thousand tons of CO<sub>2</sub> emitted into the atmosphere (Braskem S.A., 2021).

According to data released by the European Bioplastics Association by São Paulo State Research Support Foundation (2019) bioplastics represent less than 1% of the total plastic (in millions of tons) produced annually in the world. However, despite the low value when compared to plastic of fossil origin, it is mentioned that between 2018 to 2019, there was an expansion of 5% compared to previous years. The expectation is that the number and investments in biopolymers will continue to evolve, reaching the mark of 2.4 million tons, in 2024.

Therefore, when we look at the overall picture presented, still taking into account the current world demand for PVC in the world presented above, we can say that the green polymer area is constantly developing with investment in new technologies, evaluating new types of resins and raw materials thus showing that there is room on the market for bioplastics.

#### **5.4.1.1. Market positioning**

The product to be marketed by BiPlastic is green PVC resin from sugar cane. Its great differential is the non-use of fossil sources, which results in a product that is less harmful to the environment in relation to the current production of plastic.

In relation to its cost benefit, as pointed out by the researcher at the Biofabris National Institute of Biofabrication in Brazil, André Luiz Jardim Munhoz, the cost of producing the resin made from sugar cane ethanol is practically the same as that of plastic originated from Petroleum. However, as pointed out by the author, there are customers, through market research, who are willing to pay between 35 and 40% more for packaging and utensils that have some type of green certification (World of Plastics, 2017).

Regarding the consumption of PVC, it is the third most consumed and produced thermoplastic in the world and the fifth in Europe, with forecasts of expansion of the area requiring an increase in the gradual production of resin (PlasticEurope, 2020; Chemistry and derivatives, 2019).

Therefore, from these points, it is possible to observe that BiPlastic will be able to position itself in the market because it is located in a chemical zone of high influence and is producing a high consumption product combined with green marketing associated with new consumption patterns. The next sections concern suppliers, customers and competitors, sections necessary for a complete assessment of the market in which the company intends to enter.

#### 5.4.1.2. Suppliers

For the expected production of 800,000 kg of biopolymer per year, it will be necessary to supply the company with its raw materials and other inputs that route production. Table 23 shows the main inputs, suppliers, and their location in relation to BiPlastic. The quantities that will be used are the same data as shown in Tables 4 and 16.

**Table 23.** Main inputs and suppliers for the BiPlastic process.

raw material	suppliers	Location
Suspension agent	Corbion	amsterdam
Initiators	Corbion	amsterdam
Monomer	Corbion	amsterdam
Compressed Dry Air	Air Liquide	Chemical Complex of Estarreja

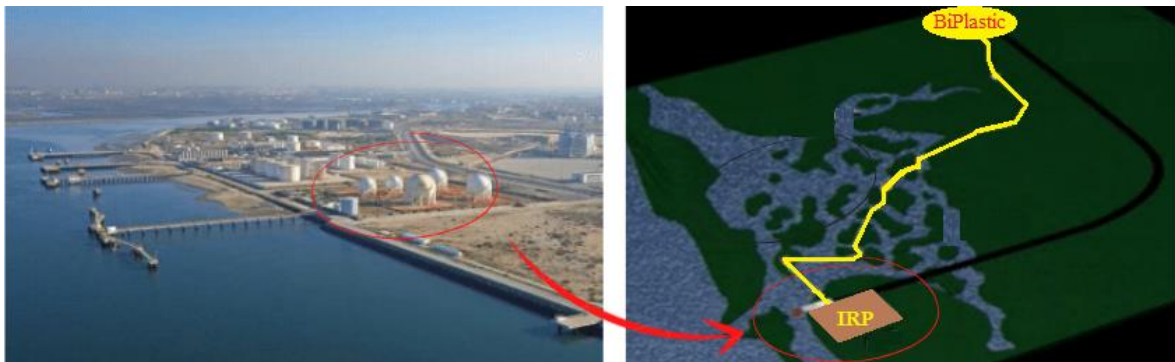
Source: Own elaboration

Considering the possibilities for purchasing the main inputs that involve the production of bioplastic, the choice of companies that will supply the inputs is related to the location and the proximity to the sea for transportation and the compatibility between the companies' values. The Corbion company has the slogan "Preserve what matters" presenting a catalog with sustainable sections and renewable raw materials. The company Air liquide was chosen due to its proximity,

as it is within the same chemical complex, which will facilitate the transportation and use of the input provided by it.

In relation to the transport of liquefied monomer, sea transport will be used by boat to the Port Reception Facilities, IPR, located in the Chemical Terminal of the Port of Aveiro, in Gafanha da Nazaré. This choice is made by reference to the company CIRES, which uses the same port to receive its raw material. For storage, four tanks will be used, called IP-1 to IP-4, with a volume of 5,000 m<sup>3</sup> and later through a pipeline transported to the company. Therefore, the supply of the raw material will be carried out during the year, aligning the production of the company Corbion with the logistics of delivery with reference to the production and availability of BiPlastic to store the raw material.

Figure 39 refers to the port where the raw material and pipeline will be received to the company, represented by the yellow line.



**Figure 39.** Porto de Aveiro and pipeline from Porto to the company.

Source: Adapted from CIRES (2017).

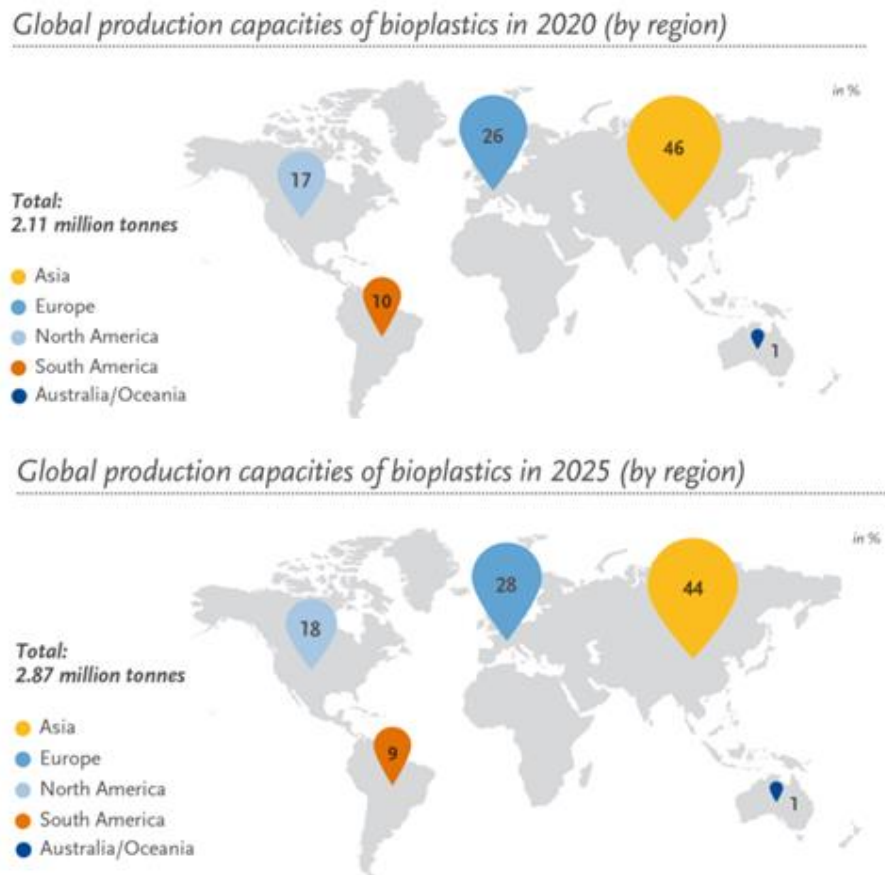
### **5.4.1.3. Customers and competitors**

The value of producing biopolymers from renewable sources has the same price in relation to polymers with fossil sources because both have the same processes, and only the scale or quantity that can be made can vary. However, in the case of biopolymers, when the production value of the monomer is added, which includes the value of the purchase of raw material and its transport in addition to its production process, the value can reach up to three times more in relation

to the monomer for oil usually used (Fundação de Amparo à Pesquisa do Estado de São Paulo, 2020).

However, as already mentioned, due to the positive marketing that the product will have and the appreciation of a new class of consumers who are more concerned with what they consume and invest, the difference between prices will not be a determining factor when selecting the product to buy, when compared to a possible competitor that uses fossil sources as raw material.

In relation to the current consumption of bioplastic in Europe and the world, Figure 40 shows in percentage the distribution of the use of bioplastic in relation to its production. The forecast proposed by PlasticEurope (2020), is that there will be an increase in the consumption and production of bioplastics between 2020 and 2025. Another significant point is the percentage increase in Europe, from 26 to 28% showing interest in the market beyond the political incentive in reducing the amount of plastic produced.



**Figure 40.** Global percentage of bioplastic production in 2020 and 2025.

Source: Adapted from PlasticEurope (2020).

Therefore, given that there is current demand and forecast of increase, BiPlastic intends to consolidate itself initially as a B2B seller for molding companies mainly for the cosmetics and food industries, industries that will benefit from the production and marketing proposed by the company.

The main sales strategy will be based on expanding and reselling the bio resin to the largest possible audience, expanding the brand, and increasing the public's contact with the material. Companies such as PolibagTCI packaging, Eurogrip, Monouso, Bionatics, Codeplas Plásticos and Danipack will be the first customers that BiPlastic intends to reach because they are already within the company's target audience in addition to being in Portugal.

Despite being a company with the idea of a new and innovative product, BiPlastic may present difficulties due to its competitors because it is a new brand in the polymer market. Companies that already have a large structure, with name, brand, and production possibilities in addition to having a well-established range of customers will be their main competitors. In addition to being already known and having greater visibility in the market, their prices tend to be cheaper, due to the quantity that is produced in addition to the wide range that these companies serve.

In Europe, the main companies that fit these characteristics are Formosa Plastics Corporation, Covestro AG, Shin-Etsu Chemical Co. Ltd., Westlake Chemical Corporation, LG Chem and Braskem (Mordor Intelligence, 2020).

To circumvent this reality, the company intends to reach an audience that is initially different from what these companies serve using, as already mentioned, green marketing and the non-use of fossil sources in its favor. In other words, competition between such companies is not because they reach the same target audience, but because of the price included in the process and mainly in the product to be sold.

#### **5.4.2. Pricing**

The greatest competition existing between products supplied by structured and consolidated companies that use fossil sources as raw material and the product intended by BiPlastic is the total price attributed to it. In addition to the differentiated use of the raw material, some points must be considered when it comes to the pricing process for BiPlastic. The first is the

non-possession of the means of production of the monomer. Therefore, the amount that will be paid for the monomer, at first, will be the sum of the value of the sugar cane and its processing in ethanol and later in ethylene and the production of the monomer and its transport to the base in the Port of Aveiro.

The second is the initial price of the PVC resin monomer production facilities that will have to be distributed in the value of the products over the years so that a positive cash flow occurs over time. When comparing the processes of consolidated companies in which such additions are not necessary or that, due to the high volume of production, the price imbued in the product to be sold is better dissipated, therefore, relatively small, the cost of the BiPlastic product will eventually be higher.

According to data released by Formosa Plastics on its official website, Chembid, a site specialized in chemicals and plastics worldwide and exposed by Statista (Figure 41), in 2020 the ton of poly(vinyl chloride) from fossil sources was \$885 a ton.

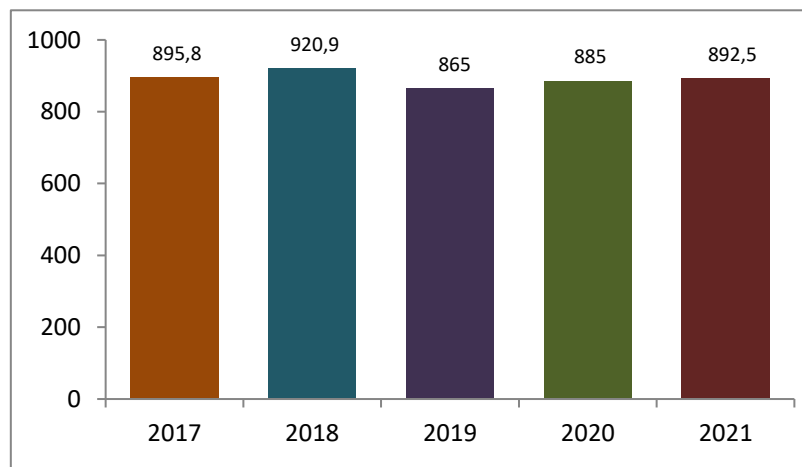


Figure 41. Price ratio of poly (vinyl chloride) from fossil sources between 2017 to 2021.

Source: Adapted from Statista (2021).

The price per ton of PVC with monomer from natural sources varies between 1,516 and 3,147 dollars per ton (World of Plastics, 2017; Rossell, Mantelatto & Leal, 2002).

An important point when mentioning this value is its direct relationship with the price of sugar cane. According to Rossell et al. (2002), this relationship can alter the final price of the

product by up to 29%. Another direct relationship with the price of the product is the amounts spent on electrical and thermal energy used in the process, varying its final price by 11%.

A relationship between both productions is the dependence on their costs, on different scales, with the price of oil. While for the production that uses it as a source of basic raw material, the change in its value directly affects the value of its by-products, the value of which changes in distribution, logistics and the need to use sugar cane for other purposes, potentially increasing its market value. As pointed out by professor at Fundação Getulio Vargas Marcos Fava Neves in an interview given to the National Bioenergy Union (2021), the price of a barrel of oil in March 2020 was approximately US \$ 20 dollars. In February 2021, the price reached US \$ 66 dollars.

The increase in relation to its value is directly related to the pandemic COVID-19 experienced in 2020 and 2021 due to the continuous extraction of the resource but less demand by the market, which caused a friction between supply and demand, reports Neves (2021). With the rise of oil, the alternative found is its momentary substitution by ethanol, which increases the amount of consumption of this, which results in a greater need for raw material, which among others, is sugar cane. This high demand also causes its price to increase, thus varying other by-products for which the ethanol produced is destined (Biasioli, 2021).

Regarding sugar cane, despite the difficulties faced by the sector due to the COVID-19 pandemic, Brazil (the largest producer and exported of the product worldwide) produced, in 2020, about 642.7 million tons, 3.6% more compared to the 2019 harvest. The volume of ethanol exported from sugarcane was 2.2 billion liters, 38% higher than the volume exported in 2019 with an average price of US\$ 442.51 per thousand liters (Biasioli, 2021).

Therefore, it can be seen that the current scenario in relation to production and costs, although not favorable in relation to the uncertainties caused by the pandemic, are still encouraging for future investments that intend to use such raw material. The value quoted, in relation to the monomer that will be the basis for BiPlastic's production, is relatively higher than the usual price that large companies have already incorporated, whether buying from a third party or producing them, but with a well-structured target audience and with the need to have green products that do not harm the environment in the long term in conjunction with the new environmental laws that are being formulated, both in relation to disposal and in relation to the use of plastics, BiPlastic becomes a company with great possibilities to conquer its market positioning efficiently and quickly.

## **5.5. Marketing Plan**

According to Gonzaga (2005) product differentiation marketing has as its main tool the creation of a beneficial characteristic that is perceived as a significant value to the point of being the reason for choosing its consumption, and such benefits include mainly non -financial, such as the intangible benefits of their consumption. The great objective of marketing is to motivate enough individuals willing to pay the minimum price that justifies their commercialization.

Despite the fact that BiPlastic focuses on B2B trade with companies that will acquire green resin and, in turn, model this for the final products that will reach consumers, the company, as it is entering a branch already consolidated, but with a new one proposal presenting an innovative product that has a higher price than usual, the need to work on marketing both in the sale of your product to the modeling companies, as well as in the consultancy and monitoring of these companies for the sale and their products, if made it present and necessary.

The main objective of BiPlastic's marketing is to make the company's brand recognized by the large consumer public, which, in turn, will look for products with its logo, which will cause the modeling companies to buy their resin. Therefore, the main strategy will be to conquer the final consumer, gaining market and notoriety.

The main tool to be used will be green marketing. The term refers to the marketing instruments associated with the product and the production that explores all the environmental benefits associated with them, having as a central theme the sustainability of the planet's ecosystem. The long-term creation of social demand, status for purchasing and consuming products that maintain these references to the environment, as well as greater restrictions over time through government policies for the use of non-renewable sources will be factors that will influence marketing (Gonzaga, 2005).

Green marketing, according to Polonsky (1994), is the set of activities designed to produce and facilitate trade in products or services to satisfy human needs. However, causing the minimum impact on the environment, which may involve the modification of products, packaging, changes in processes or sources of raw materials. Green marketing is closely linked with the idea that the target audience wants a cleaner and more conserved environment and is willing to pay for it.

Consumers, the target audience that BiPlastic intends that molders reach when using their resins/brand are considered, according to Ottman (1998), as environmental consumers, who,

because they are motivated by the need to make a difference, maintain a lifestyle involved small actions that make them comfortable, looking for products that have such environmental impacts and that bring the feeling of being doing their part for the environment. Such a sensation is known as "empowerment".

### **5.5.1. Commercial strategy**

The commercial strategy that will be adopted by BiPlastic will be to reach the final public emphasizing all the characteristics that the products made from the resin present. The use of social networks and media as a way of extending reach to explain the advantages of using products associated with the company's brand and seal (Figure 42) to the end consumer, demonstrating the low ecological impact of manufacturing, the use of resources sustainable products that contribute from their harvest to the entire subsequent product cycle (production, use and disposal) are points that will be explored to achieve the buyer's lasting satisfaction when purchasing their products.

For this, it will be requested in joint communion by the modeling companies that the company seal, which complies with all the mentioned characteristics be placed together with the product. This seal will be the link between BiPlastic and all the green marketing that the company will be working with the media. With this, the molders will be benefiting from being placed on the market a product already reached by consumers, selling more products that use the resin purchased and acquired by BiPlastic, thus bringing more revenue and possible customers to the company.



**Figure 42.** BiPlastic seal.

Source: Own elaboration

An important point that must be emphasized is the responsibility assumed by the modeling companies in relation to the environment. As already mentioned, companies that will be outsourced to purchase raw materials for BiPlastic's production have a history and commitment to

caring for the environment. Therefore, when associating the BiPlastic brand and with the entire marketing system presented to it by its products, molders and future resellers must be closely connected and committed to the environment.

As these are products with possibilities for reuse and biodegradation, it is expected that the brand will not be associated with any type of harm or disservice to the environment.

### **5.5.2. Environmental certifications**

The search for environmental certifications will be one of BiPlastic's priorities to establish its responsibility and mission towards the environment. The main function of certificates is to ensure that the market and customers have an effective environmental concern based on their actions and processes focused on sustainability, being strictly linked to the company's image before the public and increasing the credibility of the company's green marketing.

The main certificates that will be considered at first published by the Portugal Business Newspaper (2019), are:

- Ecolabel (EUSR): It aims to facilitate communication between manufacturer and buyer due to the good environmental performance of services;
- Carbon Trust Standard: It aims to demonstrate companies that aim to reduce the environmental impact with more efficient processes, in relation to the consumption of energy, water and CO<sub>2</sub> emissions;
- ISO 14001: International certificate to ensure compliance with environmental legislation and the reduction of actions harmful to the environment.

### **5.5.3. New consumption pattern**

According to BCSD Portugal (2019), which represents the business association of Portugal focused on a more sustainable world, it states that among the consumption trends, in relation to the coming years, the commitment to sustainability stands out.

Also according to BCSD Portugal (2019), an evaluation carried out with 30 thousand consumers in 60 different countries that the brands that demonstrate a commitment to sustainability surpass, in number of sales, the brands that do not, stating that, about 73% of the Millennial generation, whose growth accompanied the disclosures and teachings about the environment within schools and media and who currently represent the largest percentage of the active population with purchasing power, are already willing to pay more for sustainable products.

The market research also mentions that 43% of consumers look for certain brands for their purchase in connection with logos, stamps and certifications related to the environment. Therefore, from such research it is possible to associate that the marketing appeal adopted by BiPlastic when adding its stamp on the products may cause an increase in sales and consumption of these (BCSD Portugal, 2019).

According to BCSD Portugal (2019), there are some positive actions in relation to marketing that can reach the target audience, namely:

- **Work in communities:** Identify a community in which, a change in the environmental part can bring visible results, inspiring other people to act and discover who were responsible for such change, generating organic engagement for the company;
- **Communicate in images:** Use simple and visual language to create a connection between the company / brand and the public;
- **Invoking emotion with intention:** Create contexts where the audience connects the brand / logo with pleasurable feelings;
- **Create calls to action:** Create campaigns so that the public can do something they can do and know how to do, creating a direct connection between day-to-day actions with the brand;
- **Telling stories:** Create contexts and stories so that the brand can promote changes and that they are related together.

Therefore, one must always consider the actions taken to authenticate the brand with the public to ensure their success in sales and acceptance.

## 5.6. Financial evaluation

As indicated by Seider et al. (2009), generating net profit is not indicative to consider whether a chemical project is profitable since the profit generated during the lifetime must be greater than the capital originally applied, therefore, the enterprise will be considered more attractive when the greater the excess profit generated by the venture. For your determination, cash flow, simple payback, and discounted payback, as well as the net present value and internal rate of return will be executed in the next sections.

### 5.6.1. Cash flow

Cash flow is based on investment estimates, operating costs, and sales revenues over the years. In general, a company's first cash flows are for the payment of engineering costs, equipment, and the construction of the plant. In sequence, sales revenues and operating costs integrate cash flows (Towler & Sinnott, 2008).

Table 24 indicates all costs calculated to facilitate visualization. As already calculated, BiPlastic's annual revenue will be \$ 2,317,600.00, and it is necessary that this amount be paid annually with the costs of utilities, employees, and labor. The other amounts will be divided into installments according to the company's possibilities and will be shown in Table 25.

**Table 24.** BiPlastic cost estimation.

Costs	Estimated Costs (Dollars)
Labor (annual)	873,600.00
Equipment (total)	2,223,293.00
Raw material (annual)	482,667.00
Utilities (annual)	423,695.60
BiPlastic annual revenue	<b>2,317,600.00</b>
Total project cost	<b>5,103,668.20</b>

Source: Own elaboration

The cash flow will be assembled considering the annual inflows and outflows to determine the time that the project will start to make profits for investors. For that, according to Table 24 there are some values that should be discounted annually and that will be known as fixed expenses, being they, labor, raw material, and utilities. It is worth mentioning that, in the first year, fixed expenses are already included in the total value of the project and will only be discounted from the second year. Therefore, the expectation is that in the first-year production begins and thus, revenue from sales of the green polymer starts.

According to Banco de Portugal (2021), to finance amounts greater than 1 million euros in Portuguese banks, the interest rate was approximately 1.7% in October 2020. Therefore, to work with a safety margin due to possible fluctuations that can be obtained at such rates, interest of 2.5% per year will be applied. It will be assumed that to start the project, the creators will have 25% of the total value, therefore it is necessary to finance 75% of the total value of the project that will be paid to the bank in 5 years in equal installments, considering the interest rate. Therefore, the total amount to be financed by the bank will be 3,827,751.73 dollars.

In order to define the amount that must be paid to the bank per year at the specified time of the loan, the increase in net benefit (ABL), shown by Equation 11, will be calculated from the data provided by General Deposit Box (2021).

$$ABL = VLA \times FRC$$

**Equation 11**

Since VLA is the updated net amount, that is, the gross amount that will be financed by the bank and FRC is the capital replacement factor that the investor will have, considering the payment time and the interest imbued in the amount, which is calculated from Equation 12.

$$FRC = \frac{i}{1 - (1 + i)^{-t}}$$

**Equation 12**

Where "i" is the interest rate charged and "t" is the time it will take. Substituting the values of "i" for 2.5% and "t" for 5, we find that the FRC value is equal to 0.215247. Substituting this

value in Equation 11, knowing that the value of the VLA is 3,827,751.73 dollars, we find that the value, per year, of the installment that must be paid to the bank is 823,911.55 dollars. As a result, the total amount of interest that will be paid to the bank is \$ 291,806.02.

With the calculated values, it is possible to calculate the cash flow, which is shown in Table 25. The cash flow will be realized considering a period of 15 years due to possible needs for equipment renovations in addition to being the minimum time that is expected to have a financial return with the company in question.

Table 25. BiPlastic cash flow.

Time (year)	annual revenue	Raw material (Yearly)	Labor (Yearly)	Utilities (Yearly)	medium- and long-term debt service	Cash flow	Accumulated Cash Flow
1	2,317,600.00	482,667.00	873,600.00	423,695.60	823,911.55	-286,274.15	-286,274.15
2	2,317,600.00	482,667.00	873,600.00	423,695.60	823,911.55	-286,274.15	-572,548.3
3	2,317,600.00	482,667.00	873,600.00	423,695.60	823,911.55	-286,274.15	-858,822.45
4	2,317,600.00	482,667.00	873,600.00	423,695.60	823,911.55	-286,274.15	-1,145,096.6
5	2,317,600.00	482,667.00	873,600.00	423,695.60	823,911.55	-286,27.15	-1,431,370.8
6	2,317,600.00	482,667.00	873,600.00	423,695.60	-	537,637.40	-893,733.35
7	2,317,600.00	482,667.00	873,600.00	423,695.60	-	537,637.40	-356,095.95
8	2,317,600.00	482,667.00	873,600.00	423,695.60	-	537,637.40	181,541.45
9	2,317,600.00	482,667.00	873,600.00	423,695.60	-	537,637.40	719,178.85
10	2,317,600.00	482,667.00	873,600.00	423,695.60	-	537,637.40	1,256,816.3
11	2,317,600.00	482,667.00	873,600.00	423,695.60	-	537,637.40	1,794,453.7
12	2,317,600.00	482,667.00	873,600.00	423,695.60	-	537,637.40	2,332,091.1
13	2,317,600.00	482,667.00	873,600.00	423,695.60	-	537,637.40	2,869,728.5
14	2,317,600.00	482,667.00	873,600.00	423,695.60	-	537,637.40	3,407,365.9
15	2,317,600.00	482,667.00	873,600.00	423,695.60	-	537,637.40	3,945,003.3

Source: Own elaboration

As can be seen from Table 25 from the 8th year onwards, the company will start to show profits. Until the 5th year, all medium and long-term debts made with the financier to open the company must be paid, and the company will be in the red until its 7th year.

As the cash flow will be in the red during the first 5 years, it will be considered that the company will need a new loan, however in the long term to fill the deficit generated, that is, making a new loan with the total amount of the negative balance it will be possible to have a new entry in the year, of the same amount as the deficit, to reset the cash flow. With that, for the year in question, all debts will be paid for a good functioning of the process and the company.

This new debt will be paid from the 6th, and the interest rate will be the same as indicated by the General Deposit Box (2021). The total amount of the loan will be \$ 1,431,371, and with an interest rate of 2.5% the amount to be paid to the bank will be \$ 1,540,490.50, being paid in 5 installments of \$ 308,098.10. between year 6 and 10.

Table 26 shows how the accumulated cash flow will be considering the entry of this new loan (entry from new debt) and the collection of this (long-term financing).

**Table 26.** Cash flow with new loan.

<b>Time (year)</b>	<b>annual revenue</b>	<b>Fixed costs (Yearly)</b>	<b>medium-term debt service</b>	<b>Entry from new debt</b>	<b>Long-term financing</b>	<b>Cash flow</b>	<b>Accumulated Cash Flow</b>
1	2,317,600.00	1,779,962.60	823,911.55	286,274.15	-	0.00	0.00
2	2,317,600.00	1,779,962.60	823,911.55	286,274.15	-	0.00	0.00
3	2,317,600.00	1,779,962.60	823,911.55	286,274.15	-	0.00	0.00
4	2,317,600.00	1,779,962.60	823,911.55	286,274.15	-	0.00	0.00
5	2,317,600.00	1,779,962.60	823,911.55	286,274.15	-	0.00	0.00
6	2,317,600.00	1,779,962.60	-	-	308,098.1	229,539.30	229,539.30
7	2,317,600.00	1,779,962.60	-	-	308,098.1	229,539.30	459,078.60
8	2,317,600.00	1,779,962.60	-	-	308,098.1	229,539.30	688,617.90
9	2,317,600.00	1,779,962.60	-	-	308,098.1	229,539.30	918,157.20
10	2,317,600.00	1,779,962.60	-	-	308,098.1	229,539.30	1,147,696.50
11	2,317,600.00	1,779,962.60	-	-	-	537,637.40	1,685,333.90
12	2,317,600.00	1,779,962.60	-	-	-	537,637.40	2,222,971.30
13	2,317,600.00	1,779,962.60	-	-	-	537,637.40	2,760,608.70
14	2,317,600.00	1,779,962.60	-	-	-	537,637.40	3,298,246.10
15	2,317,600.00	1,779,962.60	-	-	-	537,637.40	3,835,883.50

Source: Own elaboration

Figure 43 shows the graph that represents the accumulated cash flow of Tables 25 and 26, respectively

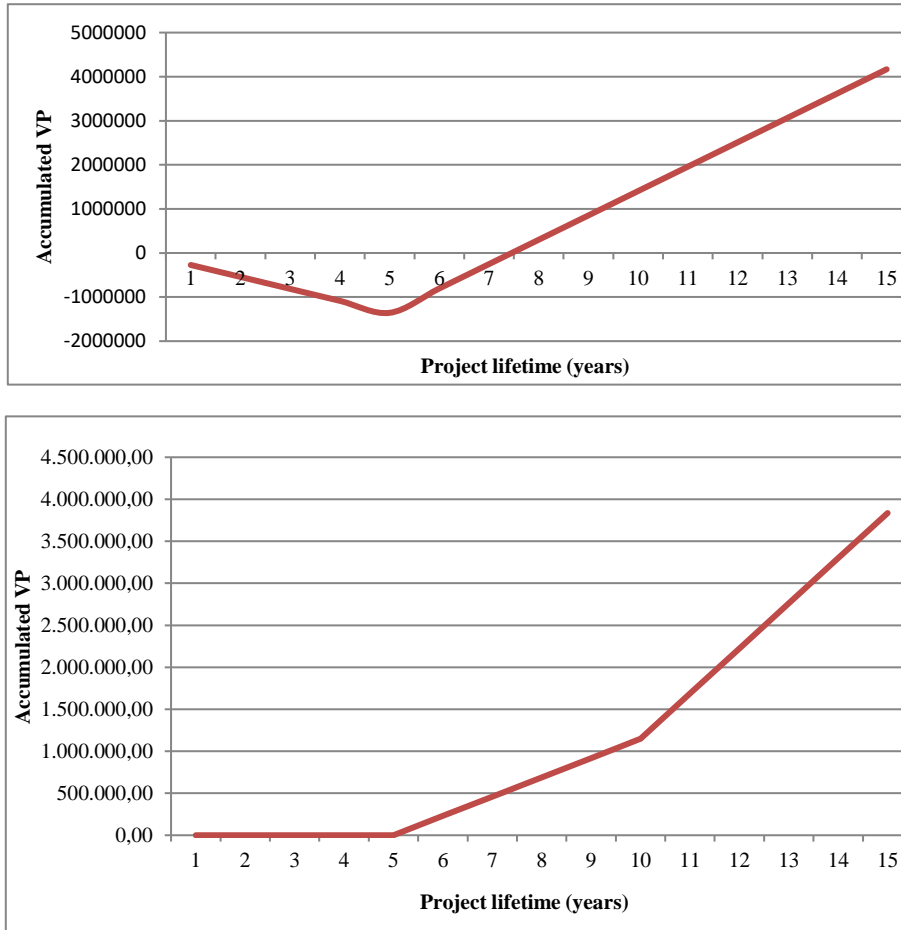


Figure 43. Trend graph of accumulated cash flow from Table 25 and 26, respectively.

Source: Own elaboration

As you can see from the figures, with the new loan to the company and its payment after 5 years of its fundraising, BiPlastic will not go through any moment in the red, that is, with negative balance, which will give it vitality to continue business and already manage to produce in its first year of installation.

### **5.6.2. Net Present Value (NPV) and Internal Rate of Return (IRR)**

According to Towler and Sinnott (2008) the net present value, or NPV, is the sum of future cash flows brought to present value, that is, to know the current value of an investment and its profitability using a discount rate in the calculation, known as the Minimum Attractiveness Rate (TMA). Equation 11 concerns the calculation of NPV.

$$NPV = \sum_{j=1}^n \frac{FC_j}{(1 + TMA)^j}$$

**Equation 13**

Of which: NPV - Net Present Value;  $FC_j$  - Cash Flow in year  $j$ ;  $j$  - period of each cash flow. A period of 15 years will be assumed, as indicated by Table 25 and, for comparative bias, two TMA of different values: 10% and 5%. The results are shown in Table 27.

**Table 27.** NPV values at 10 and 5%.

<b>Time (year)</b>	<b>annual revenue</b>	<b>Cash flow</b>	<b>NPV (TMA 10%)</b>	<b>NPV (TMA 5%)</b>
1	2,317,600.00	-286,274.15	-272,642	-272,642
2	2,317,600.00	-286,274.15	-259,659	-259,659
3	2,317,600.00	-286,274.15	-247,294	-247,294
4	2,317,600.00	-286,274.15	-235,518	-235,518
5	2,317,600.00	-286,274.15	-224,303	-224,303
6	2,317,600.00	537,637.40	401,193.3	401,193.3
7	2,317,600.00	537,637.40	382,088.9	382,088.9
8	2,317,600.00	537,637.40	363,894.2	363,894.2
9	2,317,600.00	537,637.40	346,565.9	346,565.9
10	2,317,600.00	537,637.40	330,062.7	330,062.7
11	2,317,600.00	537,637.40	314,345.5	314,345.5
12	2,317,600.00	537,637.40	299,376.6	299,376.6
13	2,317,600.00	537,637.40	285,120.6	285,120.6
14	2,317,600.00	537,637.40	271,543.4	271,543.4
15	2,317,600.00	537,637.40	258,612.8	258,612.8
<b>Total</b>			966,039.8	2,013.387

Source: Own elaboration

The Internal Rate of Return or IRR is the interest rate so that the net present value is equal to zero. The analysis of the enterprise must be taking into consideration the value of the IRR in relation to the NPV and TMA. It can be calculated directly via excel from the cash flow already calculated (Seider et al., 2009).

Table 28 presents the criteria used in the analysis of NPV and IRR according to Seider et al. (2009) and Table 29 the tabulated results of both calculated values.

**Table 28.** Criteria for the analysis of NPV and IRR.

Result	Project analysis
IRR < MAR	Impracticable
IRR = MAR	Indifferent
IRR > MAR	Viable
IRR >>> MAR	Attractive
NPV < 0	Impracticable
NPV = 0	Indifferent
NPV > 0	Viable
NPV >> 0	Attractive

Source: Seider et al., 2009.

**Table 29.** Result IRR and VPL BiPlastic.

Economic scenario	MAR 10%	Economic scenario	MAR 5%
IRR	17%	IRR	17%
NPV	966,039.807	NPV	2,013,387

Source: Own elaboration

From Table 29 and based on Table 26, we can see that in the first scenario, with 10% MAR, the NPV is greater than zero but the IRR is equal to the MAR. The second scenario, the NPV is greater than zero and the IRR is greater than the MAR, so we can assume that it is a more viable and attractive scenario than the first one presented.

## 5.7. Strategic evaluation

BiPlastic's main strategy is to launch an innovative product with characteristics of its process that are linked to the social and environmental issues of the moment, which is the use of a renewable source to process biopolymers.

Marketing intends to relate the company's brand to the final product, using media resources to demonstrate that products with the BiPlastic brand cause less negative impacts when consumed, exploring themes such as sustainability to reach a new consumer audience.

Regarding the process, BiPlastic has an ascension plan divided into three phases. The first, and current, concerns the production of PVC bioresin by purchasing the monomer previously made from sugar cane from third-party companies.

The start of production will be 800 tons with a market value of 2,697 dollars/ton. After the return of the marketing actions, over time (being open due to the monitoring of the branding of the brand), the intention is to increase production and the plant, until it equals the large companies in the industry that produce around 200,000 tons/year.

The second phase is the beginning of the monomer production process within the company, acquiring control of the entire production. As pointed out by Rossell et al. (2002), the approximate values of a production plant of 10,000 tons of monomer, together with the transformation of the raw material into ethanol and ethylene, is approximately 105,600.00 USD, counting the values of utilities, main equipment and location. This phase will be gradual to gradually meet the company's monomer needs, acting in conjunction with the purchase by outsourced companies.

The third step is to increase the range of resins produced and start producing products from the assembled resins. With marketing intertwined with the company in a structured way, BiPlastic will have a name and brand recognized by the consumer public, allowing it to become the company producing its own consumer materials, making its sale from B2B to B2C (business-to-consumer), that is, direct sales to the final consumer.

The company, throughout its productive life, must be attentive to macroeconomic problems that involve both the exploration of raw materials and the waste of resources and the disposal of its materials. As expressed by Gonzaga (2005) in the long run, the objective of environmental management will move from "pollution control" to "pollution prevention". Therefore, being aware of these three main points will in the long run, help the environment more effectively, in addition to working with the company's positive marketing.

When related to the disposal and prevention of pollution with biopolymers, we have to, because it is a biodegradable product, different from commercial plastic from fossil sources, if it is exposed to ambient conditions in a few weeks the waste would disappear and be consumed. However, studies pointed out by Noor (2020) show that although further studies on the subject are still needed, when decomposing into the environment, bioplasts can release toxic materials for it.

Therefore, two paths must be taken to solve the problem in the short term. The first is the production of reusable products, which are not discarded after the first use, thus increasing the

useful life of the product. And the second is to implement a reverse logistics program for the collection of unusable products.

This program will be directly linked to the marketing actions and can have repercussions to help communities and NGOs that, when delivering a quantity of products, earn a percentage in cash or bonuses. This process will occur between the middle of the first stage and the beginning of the second post the construction of a space destined for the decomposition of such residues. Until such space is not completed, third party contracts must be made to deal with the waste or reuse of the product.

### **5.7.1. Economic scenarios**

The company's current scenario is to sell the formed product at a price of 2,897 USD per ton. As stated, the price is within the market price of bioresins from fossil sources, but it is still high when compared to the sale price of resins from fossil sources.

The value was chosen to support the process and the company, which for having the production of only one product, the revenue of the entire company depends on its sale and return. With the scenario in which 100% of the material produced is sold at such a value, the company's payback will be 8.6 years.

Table 30 shows the result of two economic scenarios in relation to BiPlastic's sales. The first is a pessimistic scenario, with 10% less sales and the second a positive scenario, with 10% more sales.

**Table 30.** BiPlastic sales projections.

Time (year)	Optimistic projection				Pessimistic projection	
	Fixed costs (annual)	medium- and long-term debt service	annual revenue	Accumulated cash flow	annual revenue	Accumulated cash flow
1	1,779,962.60	823,911.55	2,317,600.00	-54,514.15	2,085,840.00	-518,034.15
2	1,779,962.60	823,911.55	2,317,600.00	-109,028.30	2,085,840.00	-1,036,068.30
3	1,779,962.60	823,911.55	2,317,600.00	-163,542.45	2,085,840.00	-1,554,102.45
4	1,779,962.60	823,911.55	2,317,600.00	-218,056.60	2,085,840.00	-2,072,136.60
5	1,779,962.60	823,911.55	2,317,600.00	-272,570.75	2,085,840.00	-2,590,170.75
6	1,779,962.60	-	2,317,600.00	496,826.65	2,085,840.00	-2,284,293.35
7	1,779,962.60	-	2,317,600.00	1,266,224.05	2,085,840.00	-1,978,415.95
8	1,779,962.60	-	2,317,600.00	2,035,621.45	2,085,840.00	-1,672,538.55
9	1,779,962.60	-	2,317,600.00	2,805,018.85	2,085,840.00	-1,366,661.15
10	1,779,962.60	-	2,317,600.00	3,574,416.25	2,085,840.00	-1,060,783.75
11	1,779,962.60	-	2,317,600.00	4,343,813.65	2,085,840.00	-754,906.35
12	1,779,962.60	-	2,317,600.00	5,113,211.05	2,085,840.00	-449,028.95
13	1,779,962.60	-	2,317,600.00	5,882,608.45	2,085,840.00	-143,151.55
14	1,779,962.60	-	2,317,600.00	6,652,005.85	2,085,840.00	162,725.85
15	1,779,962.60	-	2,317,600.00	7,421,403.25	2,085,840.00	468,603.25

Source: Own elaboration

From the calculation of the projections, the IRR, NPV and Payback will be calculated, considering that the MAR will be 5%, to be able to make the financial analysis of such projections, as described in Table 31.

**Table 31.** financial analysis of BiPlastic projections.

Scenario	Optimistic	Pessimistic
MAR	5%	5%
IRR	56%	56%
NPV	4,418,976	<0
Payback	6.35 years	14.46 years

Source: Own elaboration

The pessimistic scenario considered that there will not be the total expected sales but there will still be fixed expenses, with labor, raw materials, and utilities. As for the optimistic scenario, it was considered that the price of raw materials and utilities will increase by 10% as it will be necessary to increase production to reach demand, keeping the value of labor fixed.

Therefore, from Tables 30 and 31, it is concluded that, at the very least, it is necessary that the sales volume of BiPlastic be equal to the suggested minimum.

Regarding the payment of medium and long-term debt services that were financed by a Portuguese bank and, as shown in Table 25, should be paid in 5 years, a new scenario will be built from Table 32 in which the payment of the debt will be 12 years.

Using Equation 12, under the same interest conditions, we find that FCR will be equal to 0.097487127. Substituting this value in Equation 11, knowing that the value of the VLA is 3,827,751.73 dollars, even considering that the investment for the project will be 25% of the total value, we find that the value, per year, of the installment to be paid to the bank is 3,827,751.73 dollars. As a result, the total amount of interest that will be paid to the bank will be \$ 650,126.50.

**Table 32.** Projection for 12 years of payments of medium- and long-term debts

<b>Time (year)</b>	<b>annual revenue</b>	<b>Raw material (annual)</b>	<b>Labor (annual)</b>	<b>Utilities (annual)</b>	<b>medium- and long-term debt service</b>	<b>Cash flow</b>	<b>Accumulated Cash Flow</b>
1	2,317,600.00	482,667.00	873,600.00	423,695.60	373,156.5	164,480.88	164,480.88
2	2,317,600.00	482,667.00	873,600.00	423,695.60	373,156.5	164,480.88	328,961.76
3	2,317,600.00	482,667.00	873,600.00	423,695.60	373,156.5	164,480.88	493,442.64
4	2,317,600.00	482,667.00	873,600.00	423,695.60	373,156.5	164,480.88	657,923.52
5	2,317,600.00	482,667.00	873,600.00	423,695.60	373,156.5	164,480.88	822,404.41
6	2,317,600.00	482,667.00	873,600.00	423,695.60	373,156.5	164,480.88	986,885.29
7	2,317,600.00	482,667.00	873,600.00	423,695.60	373,156.5	164,480.88	1,151,366.17
8	2,317,600.00	482,667.00	873,600.00	423,695.60	373,156.5	164,480.88	1,315,847.05
9	2,317,600.00	482,667.00	873,600.00	423,695.60	373,156.5	164,480.88	1,480,327.93
10	2,317,600.00	482,667.00	873,600.00	423,695.60	373,156.5	164,480.88	1,644,808.81
11	2,317,600.00	482,667.00	873,600.00	423,695.60	373,156.5	164,480.88	1,809,289.69
12	2,317,600.00	482,667.00	873,600.00	423,695.60	373,156.5	164,480.88	1,973,770.57
13	2,317,600.00	482,667.00	873,600.00	423,695.60	-	537,637.40	2,511,407.97
14	2,317,600.00	482,667.00	873,600.00	423,695.60	-	537,637.40	3,049,045.37
15	2,317,600.00	482,667.00	873,600.00	423,695.60	-	537,637.40	3,586,682.77

Source: Own elaboration

Thus, it is clear that, by increasing the payment time of such debt to 12 years, the cash flow will not be negative at any time since its year 1, which would allow it not to need to make a new financing.

Figure 44 shows the graph that represents the accumulated cash flow described above. It is possible to observe by the same, that, despite following a growing trend, always being positive, from the age of 12 that there are no more debts, the value increases considerably, increasing the degree of the straight line's rise.

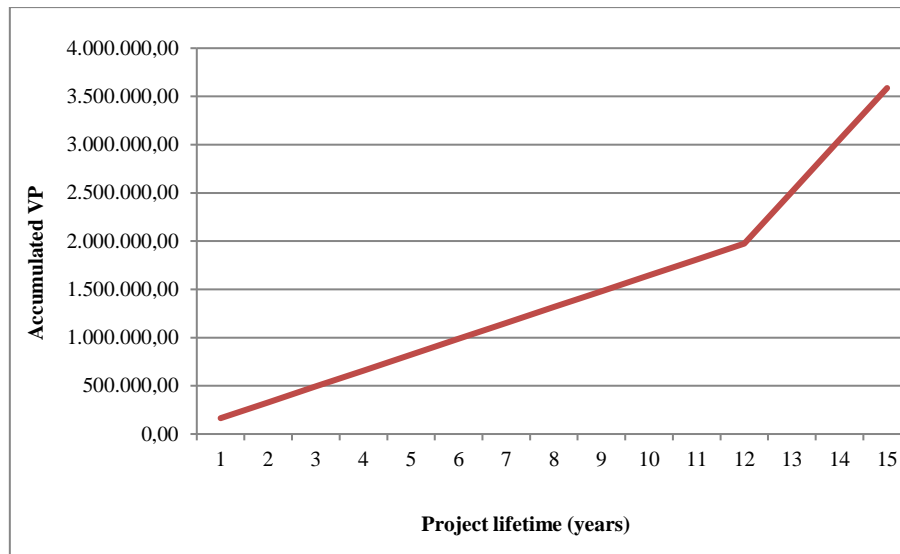


Figure 44. BiPlastic accumulated cash flow projection trend graph.

Source: Own elaboration

### 5.7.2. Financial support

According to Express Economy (2021) Portugal has reserved, from European funds, around 5 billion euros for investment, funds and benefits for companies already installed in the country and for new ones that are looking to settle.

The reduction of the energy and water tariff for large industries as well as the tax incentive and the purchase of large land for their installation are on the list of benefits that Portugal guarantees for companies in its territory.

Other supports that the country and the institutions already installed provide for new ventures and that may be used by BiPlastic, upon evaluation, are:

- Public support Programa Finicia - initiative of IAPMEI similar to the Portugal 2030 program (IAPMEI, 2016);
- Venture capital, where institutions specialized in venture capital invest in emerging companies, for a participation in the company in relation to profits (IAPMEI, 2016);

- Business Angels, where Portuguese entrepreneurs mentor and invest in business in an embryonic stage, remaining with a minority position in the company (IAPMEI, 2016).

## **6. Conclusion and future work**

The main objective of this work was to verify the economic and financial viability of the fictitious company BiPlastic based on its specificities, namely, the reuse of the vinyl chloride monomer that did not react during production and that, the product produced by the company, did not use sources fossil raw material, thus being connected to the theme of sustainability and reusing waste.

After the construction of the business plan and financial analysis, from the data calculated during the work it was possible to determine that the company will be financially viable from its 6th year of operation, presenting, as of that date, positive cash flow . However, to achieve this result, some considerations must be commented on in order to have a global view of the work presented.

For the construction of the financial analysis, a system of constant prices and values was considered based on the data found in the literature and in the communication vehicles. Its use was necessary due to the uncertainty that the financial and commercial market is in addition to that, there are not enough forecasts for the construction in the short and long term of a financial analysis.

The choice of sugar cane as the raw material for production is mainly due to the low price attributed to the product as a whole, due to the large quantity in which it is produced per year and because it is one of the secondary routes that present the largest number of researches in regarding its transformation into ethanol and later ethylene.

However, the dependence of Biplastic's production in relation to the product can be seen as something negative. A three-stage development plan was presented that, in the end, would transform the company as the owner of all stages of production that surround the production of green polymers. However, the company will still depend on the transport of sugar cane to Europe, in addition to depending on variations and quantities of annual yield, whether in relation to planting or the quality of the product. One way to solve this problem is to expand to new sources of raw materials for future production.

Another point to be taken into account is the cost proposed by the final product formed by the company. Despite being within the average market value indicated by the literature, in relation

to the price of PVC sold commercially from fossil sources, it has a very high price which, at first, may cause difficulties to enter the market and be able to consolidate your brand.

However, as presented by World of Plastics (2017), it is expected that, over time, there will be a change and replacement of niche markets, which will value more products that are concerned and have renewable sources of raw material. Therefore, despite the high price in relation to the usual, it is possible to believe that the product will be able to install itself in the Portuguese and worldwide market, since, there is demand for PVC for the next years and there are already forecasts for this new trend in the market.

Regarding the financial analysis presented, it is possible to verify that, although it is necessary to make two loans at different times, the company will be able to pay all the debts by the 10th year with only profits, disregarding the annual fixed expenses.

For future work, we intend to evaluate and design BiPlastic, based on the financial data proposed in this work, as the main producer of the vinyl chloride monomer from sugar cane in conjunction with the expansion of the production of other resins green and other sources of raw material.

## 7. References

- Allen, J. I., & Baker, T. B. (2003). Slurry tray and slurry tray assembly for use in fractionation towers. Retrieved from [patents.google.com/patent/US6830607B2/en](https://patents.google.com/patent/US6830607B2/en).
- Alsopp M. V. G. (2003). Vinyl Chloride Polymers. In *Encyclopedia of Polymer Science and Technology*, 3rd ed.; Mark, H. F., Ed. John Wiley & Sons: New Jersey, USA. Vol. 8, pp 437- 476.
- Askeland, D. R. (2008) *Ciência e Engenharia dos Materiais*, 1.ed. São Paulo: Cengage Learning,
- Bastos, V. D. (2006). Etanol, álcoolquímica e biorrefinarias. *BNDES Setorial*, v. 25, p. 5-38. Retrieved from <https://web.bndes.gov.br/bib/jspui/handle/1408/2527>.
- Bastos, V. D. (2007). Biopolímeros e polímeros de matérias-primas renováveis alternativos aos petroquímicos. *BNDES*, v.14, p. [201]-234. Retrieved from <https://web.bndes.gov.br/bib/jspui/handle/1408/11834>.
- BCSD Portugal (2019). *As marcas e a sustentabilidade*. Retrieved from <https://bcsdportugal.org/as-marcas-e-a-sustentabilidade/>.
- Biasioli, I. (2021). *Reviravolta e superação para a cana-de-açúcar*. Retrieved february 24, 2021 from <https://www.dinheirorural.com.br/reviravolta-e-superacao-para-cana-de-acucar/>.
- Bohnet, M. (2003). *Ullmann's Encyclopedia of Industrial Chemistry* [PDF]. Doi: 10.1002/14356007.o17\_o02.
- Borrelli, F. E., De La Cruz, P. L., & Paradis, R. A. (2005). Residual vinyl chloride levels in US PVC resins and products: Historical perspective and update. *Journal of Vinyl and Additive Technology*, 11(2), 65-69.
- Borschiver, Suzana, Almeida, Luiz F. M., & Roitman, Tamar. (2008). Monitoramento tecnológico e mercadológico de biopolímeros. *Polímeros*, 18(3), 256-261. Doi: <https://doi.org/10.1590/S0104-14282008000300012>.
- Braskem. (2019). *O setor petroquímico*. Retrieved January 23, 2021, from <https://www.braskem.com.br/RI/o-setor-petroquimico>.

- Braskem. (2021). Braskem investe us\$ 61 milhões na expansão da produção de biopolímeros. Retrieved March 11, 2021, from <https://www.braskem.com.br/detalhe-noticia/braskem-investe-us-61-milhoes-na-expansao-da-producao-de-biopolimeros>
- Brito, G. F., Agrawal, P., Araújo, E. M., & Mélo, T. J. (2011). Biopolímeros, Polímeros Biodegradáveis e Polímeros Verdes. *Revista Eletrônica de Materiais e Processos*, 127-139.
- Brooker, D. B., Bakker-Arkema, F. W., & Hall, C. W. (1974). Grain drying systems. In: *Drying Cereal Grains*, AVI Publishing Company, Inc., Westport, Connecticut, pp. 145-184.
- Camargo, R. F. (2017) O que é capital fixo e capital variante e qual a diferença entre eles? Retrieved March 27, 2021 from <https://www.treasy.com.br/blog/capital-fixo-e-capital-circulante>.
- Cameron, G. (2016). Process Design for the Production of Ethylene from Ethanol. Senior Design Reports (CBE), Pennsylvania, v. 14564, n. 135634, p.1- 145.
- Chauvel, A., Lefebvre, G, Leprince, P., & Marshall, N. (1989). Petrochemical process: Technical economic and characteristics synthesis gás derivatives and major hydrocarbons. Edition Technip, 2<sup>a</sup> Edição. Paris.
- Chaves, F., Cardoso, G., & Reis, E. (2015). Características do policloreto de vinila (PVC) e suas aplicações no setor da construção civil. v. 12, n. 12. Retrieved from <http://intertemas.toledoprudente.edu.br/index.php/ETIC/article/view/5419/5150>.
- ChemicalBook. (2020). Chemical product property 2,2'-azobis. Retrieved december 2, 2020, from [https://www.chemicalbook.com/ChemicalProductProperty\\_EN\\_CB3298754.htm](https://www.chemicalbook.com/ChemicalProductProperty_EN_CB3298754.htm)
- Chemistry and derivatives. (2019) .Demanda Nacional Por Plásticos Crescerá - Resinas. Retrieved july 23, 2020 from <https://www.quimica.com.br/demanda-nacional-por-plasticos-crescera-resinas/>
- CIRES. (2006). Relatório do conselho de administração (Report No. 1). Retrieved from <https://web3.cmvm.pt/sdi2004/emitentes/docs/PC8990.pdf>
- CIRES. (2017). Operacionalização da resposta a situações de emergência relacionadas com acidentes envolvendo substâncias perigosas. Retrieved february 14, 2021, from [https://apambiente.pt/\\_zdata/Instrumentos/Seveso/SessoesDivulgacao/30anosSeveso/Operacionalizacao](https://apambiente.pt/_zdata/Instrumentos/Seveso/SessoesDivulgacao/30anosSeveso/Operacionalizacao)

- Coelho, J. F. J., Gonçalves, P. M. F. O., Dionísio, M., & Gil, M. H. (2006). Characterization of suspension poly (vinyl chloride) resins and narrow polystyrene standards by size exclusion chromatography with multiple detectors: Online right angle laser-light scattering and differential viscometric detectors. *European polymer journal*, v. 42, n. 4, p. 751-763.
- De Campos, R. J., & Seo, E. S. M. (2009). Principais Aspectos da Ecotoxicologia do Cloreto de Vinila. *Revista de Gestão Integrada em Saúde do Trabalho e Meio Ambiente*, São Paulo, v.4, n.2. Retrieved from [http://www3.sp.senac.br/hotsites/blogs/InterfacEHS/wp-content/uploads/2013/08/6\\_ARTIGO\\_vol4n2.pdf](http://www3.sp.senac.br/hotsites/blogs/InterfacEHS/wp-content/uploads/2013/08/6_ARTIGO_vol4n2.pdf).
- Dimian, A. C., & Bildea, C. S. (2008). *Chemical process design: computer-aided case studies*. John Wiley & Sons. Retrieved from [www.academia.edu/11311882/Chemical\\_Process\\_Design\\_Computer\\_Aided\\_Case\\_Studies](http://www.academia.edu/11311882/Chemical_Process_Design_Computer_Aided_Case_Studies).
- Ebewele, R. O. (2000). *Polymer Science and Technology*, CRC Press, New York. Retrieved from <https://fac.ksu.edu.sa/sites/default/files/polymer-science-and-technology.pdf>
- Echemi (2020). Products information Polyvinyl alcohol. Retrieved March 27, 2021 from <https://www.echemi.com/productsInformation/pd20150901224-polyvinyl-alcohol.html>
- Endo, K. (2002), *Synthesis and Structure of Poly(vinyl chloride)*. *Progress in Polymer Science*, vol. 27, pp. 2021-2054.
- Express Economy. (2021). O Portugal 2030 pode apoiar grandes empresas. Retrieved March 29, 2021 from <https://expresso.pt/economia/2021-03-25-O-Portugal-2030-pode-apoiar-grandes-empresas--Elisa-Ferreira-explica-como-894ca8ca>.
- Faria, S. S., Siqueira, S. M., Cristino, J. H., & Rochar, J. M. (2016). Biopolímeros: uma alternativa par promoção do desenvolvimento sustentável. *Geonorte* , 61-77 Retrieved from <https://www.periodicos.ufam.edu.br/index.php/revista-geonorte/article/view/2759>
- Folha de São Paulo. (2018). Apesar dos detratores, a indústria do plástico segue de vento em popa. Retrieved July 23, 2020 from <https://www1.folha.uol.com.br/mercado/2018/07/apesar-dos-detratores-a-industria-do-plastico-segue-de-vento-em-popa.shtml>
- Fundação de Amparo à Pesquisa do Estado de São Paulo (2020). A promessa dos bioplásticos. Retrieved March 22, 2021 from <https://revistapesquisa.fapesp.br/a-promessa-dos-bioplasticos>.

- Galvez, A. (2005) Analyzing cold enzyme starch hydrolysis technology in new ethanol plant design. *Ethanol Producer Magazine*, v.11, p.58–60. 2005.
- General cash deposits (2021). *Preçário*. Retrieved may 03, 2021 from [www.cgd.pt/Precario/Documents/Folheto-Completo-Taxas-Juro.pdf](http://www.cgd.pt/Precario/Documents/Folheto-Completo-Taxas-Juro.pdf)
- Gilbert, K., (2020). Status da demanda do mercado PVC estabilizadores 2020 | Análise do setor por grandes empresas, regiões, oportunidades e previsão para 2024. Retrieved March 23, 2020 from <http://minhodiario.com/2020/07/22/status-da-demanda-do-mercado-PVC-estabilizadores-2020-analise-do-setor-por-grandes-empresas-regioes-oportunidades-e-previsao-para-024/>
- Gilbert, M., & Patrick, S. (2017). Poly (vinyl chloride). In *Brydson's Plastics Materials*. Butterworth-Heinemann pp. 329-388. Retrieved from <https://www.sciencedirect.com/book/9780323358248/brydsons-plastics-materials>
- Gonzaga, C. A. (2005). Marketing verde de produtos florestais: teoria e prática. *Floresta*, pp. 353-368. DOI: <http://dx.doi.org/10.5380/ufv.v35i2.4623>.
- Google earth maps. [maps.google.com](https://www.google.com/maps/). Retrieved March 22, 2021 from <https://www.google.pt/maps/>.
- Gorni, A. A. (2003). A evolução dos materiais poliméricos ao longo do tempo. *Revista Plástico Industrial*. Retrieved february 23, 2021 from [http://www.gorni.eng.br/hist\\_pol.html](http://www.gorni.eng.br/hist_pol.html).
- Hage Jr., E. (1998). Aspectos históricos sobre o desenvolvimento da ciência e da tecnologia de polímeros. *Polímeros*, 8(2), 6-9. Doi: <https://doi.org/10.1590/S0104-14281998000200003>.
- Hamilton, N. J. (2013). Suspension polyvinyl chloride plant. Retrieved february 11, 2021 from <https://www.prweb.com/releases/ipp/PVCplants/prweb10723195.htm>.
- Hill, T. (2000). *Operations Management: Strategic Context and managerial analysis*. New York: Palgrave.
- IAPMEI. (2016). Guia explicativo para a criação do plano de negócios e do seu modelo financeiro. Retrieved february 01, 2021 from <https://www.iapmei.pt/PRODUTOS-E-SERVICOS/Empreendedorismoinovacao/Empreendedorismo/Documentosfinanciamento/ComoElaborarPlanodeNegocioGuiaExplicativo.aspx>.

- Independent Commodity Intelligence Services (2021). Retrieved March 28, 2021 from <<https://www.icis.com/explore/resources/news/2007/11/07/9076567/vinyl-chloride-monomer-vcm-prices-and-pricing-information/>>.
- Institute for bioplastics and biocomposite (2020). Biopolymers - facts and statistics. Retrieved March 14, 2021 from <https://www.ifbb-hannover.de/en/facts-and-statistics.html>.
- Hamilton, N. J. (2013). Suspension polyvinyl chloride plant. Retrieved february 11, 2021 from <https://www.prweb.com/releases/ipp/PVCplants/prweb10723195.htm>
- Jenkins, S. (2018). Chemical engineering plant cost index: 2018 annual value [web page]. Retrieved from <https://www.chemengonline.com/2019-cepci-updates-january-prelim-and-december-2018-final/?printmode=1>
- Joint Bioenergy Institute (2011). Corn stoven to ethanol model. Retrieved March 26, 2021 from Disponivel em: <https://ipo.lbl.gov/lbnl2678/>
- Kahsnitz, J., Schirmeister, R., & Träger, M. (2009). Influence of EDC cracking severity on the marginal costs of vinyl chloride production. *Industrial & engineering chemistry research*, v. 48, n. 6, p. 2801-2809. Doi: <https://doi.org/10.1021/ie8006903>.
- Kochar, N. K., Merims, R., & Padia A. S. (1981). Ethylene from ethanol. *Chemical Engineering Progress*. AlChE, 66-70.
- Kuhn, I. N., & Dama, R. A. (2009). Empreendedorismo e Plano de Negócios. Retrieved from <https://bibliodigital.unijui.edu.br:8443/xmlui/bitstream/handle/123456789/168/Empreendedorismo%20e%20plano%20de%20neg%C3%B3cios.pdf?sequence=1>
- Labor and Employment Bulletin (2020). Regulamentação do trabalho. Retrieved february 03, 2021 from [http://bte.gep.mtss.gov.pt/completos/2020/bte1\\_2020.pdf](http://bte.gep.mtss.gov.pt/completos/2020/bte1_2020.pdf).
- Luyben, W. L. (2011). *Principles and Case Studies of Simultaneous Design*. New Jersey: John Wiley & Sons, Inc. Retrieved from <https://download.e-bookshelf.de/download/0000/5878/56/L-G-0000587856-0002361846.pdf>.
- Magnabosco, A. (2014). Braskem: produção de PVC em Alagoas bate recorde. Retrieved March 15, 2021 from <https://economia.estadao.com.br/noticias/negocios,braskem-producao-de-PVC-em-alagoas-bate-recorde,175887e>.
- Mano, E. B. (2019). *Polímeros como materiais de engenharia*. São Paulo. Blusher .

- Mano, E. B., & Mendes, L. C. (2004). *Introdução a polímeros*. - 2. ed., São Paulo. Edgard Blucher.
- Manrich, S. (2005). *Processamento de termoplásticos: rosca única, extrusão e matrizes, injeção e moldes*. São Paulo. ArtliberEditora.
- Marinelli, A. L., Monteiro, M. R., Ambrósio, J. D., & Branciforti, M. C. (2008). Desenvolvimento de compósitos poliméricos com fibras vegetais naturais da biodiversidade: uma contribuição para a sustentabilidade amazônica. *Polímeros: Ciência e Tecnologia*, 92-99.
- Marten, F. L. (2003). Semi-crystalline Polymers to Ziegler-Natta Catalysts. In *Encyclopedia of Polymer Science and Technology*, 3rd ed.; Kroschwitz, J. I., Ed. John Wiley & Sons, Inc.: Hoboken, New Jersey. Vol. 8, pp 437-475.
- Mejdell, T. (1999). Modelling of industrial S-PVC reactor. *Chemical engineering science*, v. 54, n. 13-14, p. 2459-2466.
- Mordor Intelligence. (2020). Europe Polyvinyl chloride (PVC) market - growth, trends, covid-19 impact and forecast. Retrieved March 24, 2021 from <https://www.mordorintelligence.com/industry-reports/europe-polyvinyl-chloride-PVC-market>
- Morschbacker, A. (2008). *Bioethanol based ethylene*. Centro de tecnologia e inovação. Braskem S.A. Porto Alegre.
- Nass, L. I., & Heiberger, C. A. (1976). *Encyclopedia of PVC*. V, 1, p. 271, New York: Marcel Dekker.
- National Bioenergy Union. (2021). Como o preço do petróleo afeta a indústria de etanol no brasil. Retrieved March 24, 2021 from <https://www.udop.com.br/noticia/2021/03/05/como-o-aumento-de-precos-do-petroleo-afeta-a-industria-de-etanol-no-brasil.html>
- Noor, D. (2020). Bioplástico é tão tóxico e poluente quanto os plásticos tradicionais, dizem estudos. Retrieved March 29, 2021 from <https://gizmodo.uol.com.br/bioplastico-toxico-poluente-plastico-tradicional>
- Nunes, L. R., Rodolfo Jr., & Ormanji, W. (2002). *Tecnologias do PVC*. São Paulo: ProEditores/Braskem.

- Official Journal of the European Communities. (1978). Relativa à aproximação das disposições legislativas, regulamentares e administrativas dos Estados-Membros respeitantes à protecção sanitária dos trabalhadores expostos ao cloreto de vinilo monômero. Retrieved March 12, 2021 from <https://eur-lex.europa.eu/legal-content/PT/TXT/?uri=CELEX%3A31978L0610>.
- Opportimes. (2018). El PVC es el tercer plástico más utilizado en el mundo. Retrieved July 23, 2020 from <https://www.opportimes.com/el-PVC-es-el-tercer-plastico-mas-utilizado-en-el-mundo>.
- Organization for Economic Cooperation and Development and the Food and Agriculture Organization of the United Nations. (2020). *Perspectivas Agrícolas 2020-2029*. Publishing, Paris, Retrieved March 20, 2021. Doi: <https://doi.org/10.1787/a0848ac0-es>.
- Ottman, J. A. (1998). *Green marketing: opportunity for innovation*. On-line ed. New York: NTC - McGrawHill. Retrieved July 21, 2021 from <https://escholarship.org/content/qt2294d5mf/qt2294d5mf.pdf?t=qcbr9k>
- Pacopar. (2020). A história do complexo químico de Estarreja. Retrieved March 27, 2021 from <https://www.pacopar.org/contents/files/historiacqe-pt.pdf>.
- Patrick, S. (2005), *Practical guide to polyvinyl chloride*; Rapra Technology Ltd.: Shawbury.
- Pereira, C. M. G. (2014). *Percepção Do Consumidor Português Relativamente Ao Consumo De Bens Alimentares Em Contacto Com Embalagens Plásticas*. Instituto Superior de Ciência da Saúde Egas Moniz (Master's thesis, Instituto Universitário Egas Moniz). Retrieved from <https://comum.rcaap.pt/handle/10400.26/7864>
- Pereira, R. A., Alves, T. B., Furtado, L. R., Antunes, A. M., & Sá, L. G. (2007). *Tendências tecnológicas e mercadológicas dos principais produtos petroquímicos básicos: Eteno e propeno*. PDPETRO.
- Peruzzo, F. M., & Canto, E. L. (2006). *Química na abordagem do cotidiano*. 4. Ed. São Paulo: Moderna, 2006
- Peters, M. S., Timmerhaus, K. D., & West, R. (2003). *Plant Design and Economics for Chemical Engineers*, 5ª Edição, McGraw-Hill.

- PlasticEurope. (2020). *Plastics - the Facts 2020*. Belgica: Association of Plastics Manufactures. Retrieved from <https://www.plasticseurope.org/en/resources/publications/4312-plastics-facts-2020>.
- PlasticEurope. (2018). *Plastics – the Facts 2018*. Belgica: Association of Plastics Manufactures. Retrieved from <https://www.plasticseurope.org/en/resources/publications/4312-plastics-facts-2018>.
- Primo, A., Araujo, A., Costa, C., Sousa, F., Júnior, P., & Dutra, V. (2017). Produção De Cloreto De Vinila Com Aplicação De Análise Hazop. Retrieved from <https://bdm.unb.br/handle/10483/20147>.
- Polizeli, R. V. (2012). Análise da indústria química baseada em matéria prima fóssil e renovável sob a ótica energética. Retrieved from <http://tpqb.eq.ufrj.br/download/industria-quimica-materia-prima-fossil-x-renovavel.pdf>.
- Polonsky, M. J. (1994). An Introduction To Green Marketing. *Electronic Green Journal*, 2. Doi: <http://dx.doi.org/10.5070/G31210177>.
- Portugal Business. (2019). Certificação ambiental: são várias as hipóteses à escolha. Negócios em rede. Retrieved March 29, 2021 from <https://www.jornaldenegocios.pt/negocios-em-rede/empresas-sustentaveis/2019/detalhe/certificacao-ambiental-sao-varias-as-hipoteses-a-escolha>.
- Rodolfo Jr., A., Nunes, L., Ormanji, W. (2006). Tecnologia do PVC/Braskem. Rio de Janeiro. Pro editora.
- Rodrigues, I. (2008). Linha de produção de PVC: Um estudo de produtividade (Master's thesis, Universidade de Aveiro). Retrieved from <https://ria.ua.pt/handle/10773/1588>.
- Rossell, C. E., Mantelatto, P. E., & Leal, M. R. (2002). Production of biodegradable plastic (PHB), sugar and ethanol in a sugar mill. *International Sugar Journal* , 321-323.
- Saeki, Y., & Emura, T. (2002). Technical progresses for PVC production. *Progress in polymer science*, v. 27, n. 10, p. 2055-2131.
- Scharz, L. B. (1995). Reciclagem: Vida longa para Plásticos. Polimeros. São Paulo. Ciência e tecnologia.
- Seider, W. D., Seader, J. D., Lewin, D. R., & Widago, S. (2009). *Product and Process Design Principles*. 3. ed. New Jersey: John Wiley & Sons, Inc.

- Serviço Brasileiro de Apoio às Micro e Pequenas Empresas. (2016). Empreendedorismo no Brasil. Retrieved March 11, 2021 from [www.sebrae.com.br/Sebrae/Portal%20Sebrae/Anexos/GEM%20Nacional%20-%20web.pdf](http://www.sebrae.com.br/Sebrae/Portal%20Sebrae/Anexos/GEM%20Nacional%20-%20web.pdf)
- Silva, B. (2020). Qual a principal fonte da eletricidade produzida em Portugal. Retrieved March 27, 2021 from <https://eco.sapo.pt/2020/08/23/qual-a-principal-fonte-da-eletricidade-produzida-em-portugal>
- Silva, P. M. (2020). Estudo da reação de polimerização do cloreto de vinila e simulação de processos (Master's thesis, Universidade Federal de São Carlos). Retrieved from <https://repositorio.ufscar.br/handle/ufscar/13751?show=full>.
- Silva, R., & Góis, L. (2013). Tecnologia para a produção e purificação do PVC. CIATEC – UPF, 5.
- Sousa, C. (2014). Estudo Do Processo De Absorção De Plastificantes Em Polímeros De PVC (Master's thesis, Universidade de Aveiro). Retrieved from [https://ria.ua.pt/bitstream/10773/13835/1/TESE\\_.pdf](https://ria.ua.pt/bitstream/10773/13835/1/TESE_.pdf).
- Stanford Social Innovation Review. (2018). The science of what makes people care. New York City : Stanford Social Innovation Review.
- Statista. (2021). Distribution of plastics converter demand in the European Union. Retrieved February 24, 2021 from [www.statista.com/statistics/869574/polymer-plastics-converter-demand-european-union](http://www.statista.com/statistics/869574/polymer-plastics-converter-demand-european-union).
- Stevens, M. P. (1999). Polymer Chemistry: An introduction. New York. Oxford University Press.
- Summers, J. W. (2005). Introduction: Chemistry and Physical Structure. In PVC Handbook, Charles E. Wilkes, J. W. S., Charles Daniels, Ed. Hanser Gardner Publications, Inc.: Cincinnati, Ohio, pp 1-6.
- Tacidelli, A. R., Alves, J. J. N., Vasconcelos, L. G. S., & Brito, R. P. (2009). Increasing PVC suspension polymerization productivity—An industrial application. Chemical Engineering and Processing: Process Intensification, Volume 48, Issue 1. Pages 485-492,
- Terra Nova. (2018). Ministro da economia visitou o complexo químico de Estarreja. Retrieved March 22, 2021 from <https://www.terranova.pt/noticia/politica/ministro-da-economia-visitou-o-complexo-quimico-de-estareja>.

- Tiglea, P., & Santos, C. C. M. (1992) Manual de biossegurança para laboratórios de química, Instituto Adolfo Lutz, Publicações Técnicas para Divulgação Interna, São Paulo, 1992.
- Towler, G., & Sinnott, R. K. (2008). Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design. Burlington, MA: Butterworth-Heinemann.
- Turton, R., Baile, R. C., Whiting, W. B., & Shaelwitz, J.A. (2009). Analysis, Synthesis and Design of Chemical Processes. 4. ed. Upper Saddle River: Prentice Hall.
- Vanin, J. A. (1994). Alquimistas e químicos: o passado, o presente e o futuro. São Paulo: Editora Moderna.
- Wieme, J., De Roo, T., Marin, G. B., & Heyderickx, G. J. (2007). Process design and control - simulation of pilot and industrial-scale vinyl chloride batch suspension polymerization reactors. *Industrial Engineering Chemical Research*, 46, 4, 1179-1196.
- World of Plastics. (2017). Por que investir em Bioplásticos. Retrieved March 23, 2021 from <https://mundodoplastico.plasticobrasil.com.br/sustentabilidade/por-que-investir-na-producao-de-bioplásticos>.