Validation of an industrial process to manufacture isosorbide bis(methyl carbonate) at pilot level

Deliverable 8.1

Market Intelligence and competitive analysis

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EXECUTIVE SUMMARY

VIPRISCAR is a research project supported by the European commission, bringing together 9 different players from 6 European countries. The research aims to validate the scaling of the industrial process to manufacture isosorbide bis (methyl carbonate). The research is based on the existing patent from Tecnalia (Patent No. ES2647085, 2017) and will be further developed throughout the project's lifetime. To proof the principle of the research, the Isosorbide bis (methyl carbonate) will be processed to produce polycarbonates and polyurethane that will serve as derivatives used for the production of coating, adhesives and catheters.

The aim of this market analysis (Task 8.1, Deliverable 8.1) is to identify and qualify the VIPRISCAR product's market uptake potential. The initial industrial focus that is adopted for the study is the coating, adhesive and catheter industry in Europe. One year into the project, this paper provides an insight into the future of these markets and the risks and opportunities that will present itself. The analysis contains important insights from stakeholders, consortium partners and external advisors.

The findings that result from the research highlight the potential for scaling of the isosorbide bis(methyl carbonate). This key trend that lies at the source of this potential is the increasing trend in environmental awareness across all industries and all parts of the value chain. Combined with an increasing motivation to overcome the safety limitations that arise with current solutions. From the 3 markets studied throughout the paper the largest immediate potential lies with industrial coating.

For the coming years of the project this paper will serve as input and insight to further develop the business plans (D8.2 & D8.3) and the exploitation plan (D8.7-D8.10).

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ABBREVIATIONS AND ACRONYMS

CAGR	Compound Annual Growth Rate
EU	European Union
FEICA	Association of the European Adhesive & Sealant Industry
GDP	Gross Domestic Product
GRAS	Generally Recognized As Safe
IBMC	Isosorbide Bis(Methyl Carbonate)
IS	Isosorbide
M&A	Mergers & Acquisitions
MDI	Methylene Diphenyl diisocyanate
MNE	Multinational Enterprise
NIPU	Non-isocyanate Polyurethane
OEM	Original Equipment Manufacturer
Pa	Per annum
Pc	Polycarbonate
PESTEL	Political, Economical, Social, Technical, Environmental, Legal
PU	Polyurethane
PUD	Polyurethane Dispersion
PVC	Polyvinylchloride
REACH	Regulation, Evaluation, Authorisation, and Restriction of Chemicals
SME	Small or Medium Enterprise
TDI	Toluene Diisocyanate
TRL	Technology Readiness Level
UK	United Kingdom
USA	United States of America
UV	Ultra Violet
VOC	Volatile Organic Compound

1. Introduction & Methodology:

Coatings and adhesives are present in every aspect of the modern society. Be it from the automotive or the construction industry to the furniture or medical sector. The current production method of these products is based on chemicals resulting from fossil fuels. Although the actual impact of the coating or adhesive used for a certain product might appear limited, it is the immense scale of the coatings and adhesives market that make it significantly harmful for the environment and for human health. This challenge has been tackled by many firms in the recent years, aiming to reduce the environmental footprint related to the use of these products. The main result of this intensive research in the field has led to the increasing share of waterborne type coatings to take increasing market share, overtaking solvent borne and powder coatings in 2016 (Olson, 2016). The same trend has been observed in the adhesives industry (Polymer Database, 2015). The uptake of these materials is because of the absence of Volatile Organic Compounds (VOCs) in this material compared to the traditional solvent or silicone-based adhesives, coatings or catheters. Nevertheless, the environmental and health impact of coatings and adhesives can still be improved beyond the existing waterborne products when considering the raw materials and end of life. This is the goal of the VIPRISCAR Project.

To achieve this goal, the patent by Tecnalia, that synthesizes isosorbide bis(methyl carbonate) from corn starch, will be further developed to Technology readiness level 5 (VIPRISCAR, 2017).

Isosorbide is a bio-based chemical that has only seen limited market development up till now but already proven record as building block for high value polymers. The production of this isosorbide based polymer however is challenging, requiring high temperatures and toxic bi-products. Enabling the environmentally friendly and efficient production of this material will have significant market interest in the near and further future. The unique technology developed by Tecnalia (Patent No. ES2647085, 2017) will be brought to the next stages through the collaboration of VIPRISCAR's technical and research partners. When the technology is ready, proof of concept and scaling will be delivered in 3 different industries, coating, adhesives and catheters. After the project's end date, the proof of concept in these industries will lead to further research of the technologies to allow for upscaling at industrial level (VIPRISCAR, 2017).

To know the ultimate market potential of the material this document will provide the industrial partners, technical and research centres, with the relevant information that drives the market today and tomorrow. The complete market analysis will assist this progress throughout the remaining time of the research project and beyond. It will serve as a guide for later deliverables such as the exploitation plans (Deliverables 8.7, 8.8, 8.9 and 8.10) and the business plan (Deliverables 8.2 and 8.3) for the innovations under development.

To make the VIPRISCAR project efficient and targeted at understanding the market exploitation potential of IBMC, the project goes beyond the market scaling and looks at the implementation of IBMC in the three most applicable sectors: Industrial coatings, hot melt adhesives and catheters. The outcome of the project after 36 months is thus segmented in 6 key exploitable results (see the Table 1).

TABLE 1: LIST OF KEY EXPLOITABLE RESULTS

No	KER Name
1	Improved IBMC manufacturing process
2	IBMC-derived coating for automotive and furniture industries
3	IBMC-based isocyanate-free coatings (NIPU)
4	Hot melt adhesives based on IBMC-derived non-isocyanate polyurethane
5	Hot melt adhesives based on IBMC-derived polycarbonates
6	IBMC-derived antithrombotic-antimicrobial catheters

1.1 Methodology:

The methodology adopted for this research report consists of several key steps. Each step will help to form a better understanding of the innovation, its industry, and its potential market. At the end of the process, a complete, coherent view of the market and its value is formed.

Overall the methodology adopted an 'ex-post facto' research method, proposed by Kothari's Research Methodology: Methods and techniques' (Kothari, 2004). This method focuses on the observation of the current situation as well as the upcoming trends in the industry. To have a complete view of the industry, the base of the research is secondary data, gathered through a literature review of scientific papers, news articles, other EU reports, and market studies. Throughout the completion of this research, the paper is completed with primary research of guided interviews and questionnaires realised by certain partners of the consortium and experts in the field.

The different stages are divided into the 4 steps. The first section will focus on the target market selection. This will select the geographical focus and customer segment. Additionally, to give a clear understanding of how the market operates a value chain analysis is conducted in this first stage. Secondly, the external market environment is studied. This is done through the PESTEL analysis that will consider each external factor that can potentially have an impact on the product over time. The third phase is the analysis, internal to the market studied. Here the research will focus on each target market separately in order to understand the right competitors and the market potential. Finally, the overall understanding of the market will be consolidated in the porter's five forces analysis. The different steps that will be conducted are visualised below (Figure 1). The different phases enable a smooth research process that is conducted in a sequential manner, requiring no unnecessary overlap. Each step in every phase will be explained in more detail throughout the paper.

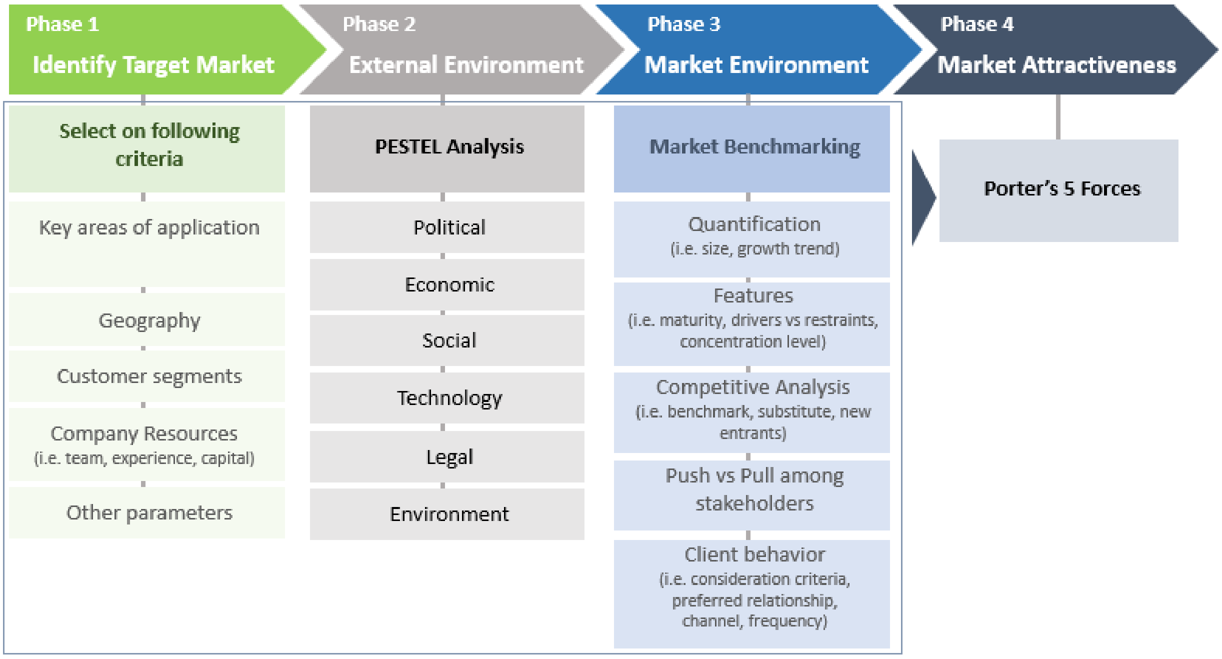


FIGURE 1: MARKETING ANALYSIS METHODOLOGY

Before the target market selection, the following paragraph provides a reminder of the technical innovation that is covered by the VIPRISCAR project. This recapitulation is necessary to understand the ultimate market value that lies behind the research.

2. Technical description of the innovation: isosorbide bis(methyl carbonate)

Throughout the chemicals industries there is an increasing trend to replace fossil resources with renewable ones. This is leading to, amongst other things, a shift from ‘chemicals from refineries’ to ‘chemicals from biorefineries’ (European Commission, 2012). One of the bio-based chemicals that has seen a significant growth throughout this period is Isosorbide. Isosorbide is a primary bio-based chemical, obtained from corn-starch derived glucose in a 2-step process (VIPRISCAR, 2017). Its key advantage is that it is easily adaptable to many derivatives with different properties and applications. It is biodegradable and is certified as ‘Generally Recognized As Safe’ (GRAS) by the Food and Drug Administration (FDA) of the US. Between 2014 and 2015 the global value of the isosorbide market grew at 8%. This growth is expected to continue and will amount to a total value of $703.15 million by 2025 (see Figure 2 (Grand View Research, 2016)).

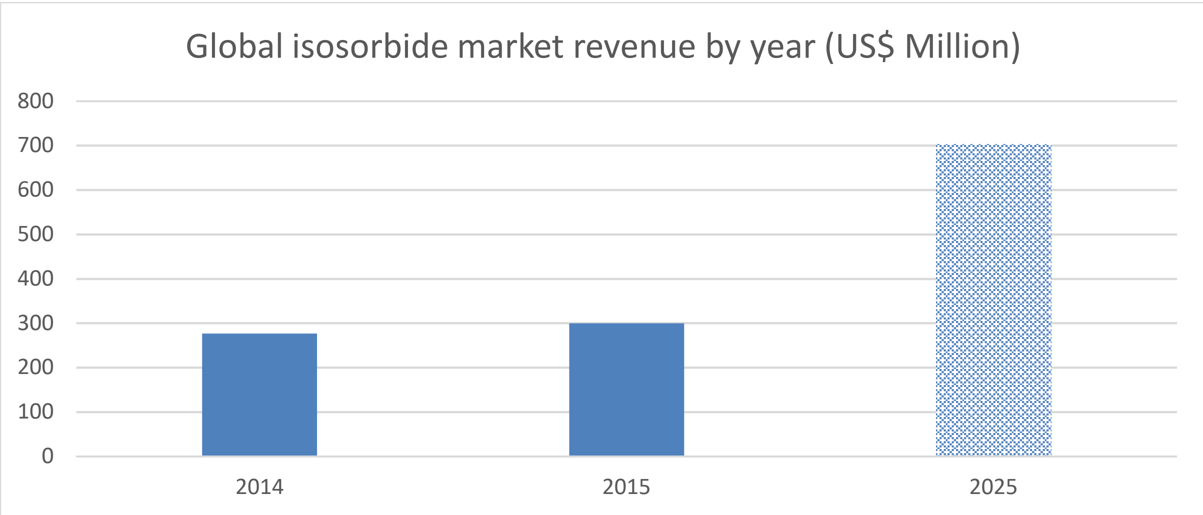


FIGURE 2: GLOBAL ISOSORBIDE MARKET REVENUE BY YEAR
SOURCE: *(GRAND VIEW RESEARCH, 2016)*

The chemical has seen a high average growth across the world. Key players include the United States, China and Germany. Overall the highest growth is estimated in Asia Pacific with a CAGR projected at 10.43% between 2017 and 2025 (see Figure 3) (Grand View Research, 2016).

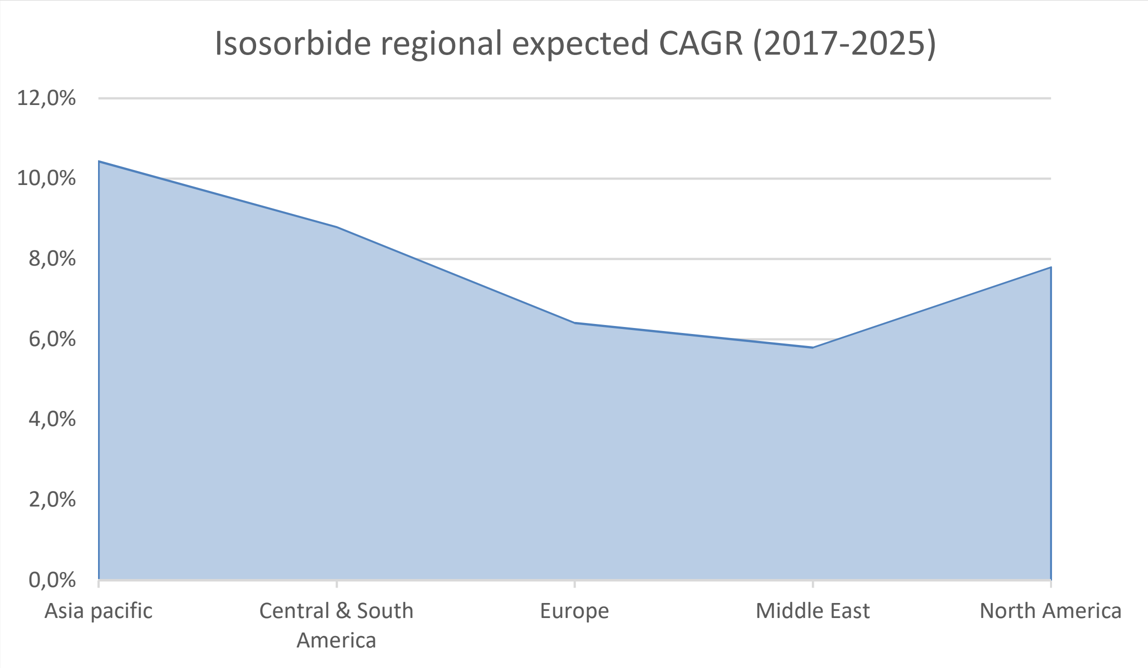


FIGURE 3: ISOSORBIDE REGIONAL EXPECTED CAGR (2017-2025)
SOURCE: *(GRAND VIEW RESEARCH, 2016)*

Despite the large demand and promising growth figures, the market volume produced is still limited. Today this volume is around 31,500 tons per year. With this limited quantity the retail price is relatively high, at €6.7/kg (Grand View Research, 2016). At this point in time there is no technoeconomic feasibility solution that would enable to reduce the cost of production. Therefore the main application areas of Isosorbide today are highly value adding. An example of this is using isosorbide as a replacement to Bisphenol A in the manufacturing of epoxy resins and polycarbonates (PCs), making food contact possible (VIPRISCAR, 2017). To obtain the isosorbide derived PCs, the current process requires melt polycondensation of IS with diphenyl carbonate, or melt polycondensation of Is-BIS(phenyl carbonate) with primary diols and triols (Noordover, Haveman, Duchateau, van Benthem, & Koning, 2011). The drawbacks of this production method however is the high temperature required to enable the reaction (240°c) and during the reaction toxic phenol is formed as co-product (VIPRISCAR, 2017).

This high demand but current inefficiency led to high investments in research by TECNALIA. With success, recent developments led to the findings of IS derived PC by melt polycondensation of Isosorbide bis(methyl carbonate) (IBMC) and 1,3-butanediol) (Ochoa-Gómez, Gil-Río, Maestro-Madurga, Gómez-Jiménez-Aberasturi, & Río-Pérez, 2016). This reaction can be enabled at lower temperature (130°C) and can be used for the synthesis of non-isocyanate polyurethanes (NIPU), opening opportunities for medical application. To scale this process, the manufacturing of IBMC needs to be optimised. The method that will enable this, transesterification of IS with Dimethyl Carbonate (DMC) using a basic catalyst, has recently been patented by TECNALIA (Patent No. US9540390B2, JP6130516B2, EP2949654B1, all of them granted in 2017). Currently this technology has a production capacity of 100ml and is developed up to Technology Readiness Level (TRL) 3.

Ultimately, the goal is to develop it further and scale up the production capacity to industrial requirements. Before this, the technology needs to be developed further and the right catalyst needs to be identified to decrease the oligomer yield to a level that is economically feasible. For this the VIPRISCAR project will bring the technology from TRL 3 to TRL 5 whilst testing the application of IS derived PCs and NIPUs in the adhesives, industrial- and medical- device sectors.

2.1 The scope of the study

2.1.1 Target market selection

Before quantifying the market, one needs to know what market should be focused on. Although certain products might have a potentially global reach, there will always be a specific sector or niche more susceptible to the technology that is being developed in the research project. The identification of this specific market segment will further guide the market analysis into valuing the exact market size and can help the further development of the product into the right direction to tailor to this market.

2.1.2 Industry

As mentioned in the technical description (see P.12) the IBMC derived PCs will be tested for the adhesives and coatings market and for biomedical application. These closely related sectors will each be the focus of the market analysis. However, within each sector there is a significant difference between different application areas. To be most aligned with the anticipated initial products that can benefit from IBMC, the research will focus specifically on the following market segments:

- For coatings the first focus is furniture and automotive. These sectors have been highlighted by the partners of the consortium at the start of the project. The specific segments most inclined to adopt the IBMC coating are chosen for two reasons. First of all, the coating is bio-based, this is an important trend at the moment. Nevertheless, the importance of coating's natural state is not only as the possibility of the recyclability of the end product but also their improved sustainability due to the bio-based nature of the materials and the ack of or lower use of isocyanate and VOCs. Traditional wooden furniture is therefore a great match for initial market implementation. Secondly, the automotive sector has been selected as this industry is expected to change drastically over the coming years, leaning more and more towards electrical vehicles (See PESTEL analysis P.24). The key challenge with electrical vehicles at the moment is the battery range. Solar reflecting paints and lightweight coating are solutions that can alter this battery range by reducing the weigh and limiting the required air-conditioning required (Furlong, 2017).

- For adhesives, the key selected segment is hot melt adhesives. This segment is selected above other types of adhesives for similar reasons as the coating segments. Hot melt adhesives are mainly used for industrial application.
- Finally, the use of IBMC derived NIPUs in the biomedical sector will be analysed through the introduction in the catheter market. This alternative market is a potential market segment as the patented process by Tecnalia (Patent No. ES2647085, 2017) enables the synthesis of NIPUs through reaction with diamines. Increasing awareness about the health and environmental damage of the current, isocyanate-based catheters will facilitate the market uptake of the VIPRISCAR technology in this sector.

2.1.3 Geography

The coatings and additive industries are generally assessed on a worldwide basis. As will be developed throughout the paper, this is because of the value chain as a whole, and the standardization of product requirements. Most large enterprises that are involved in VIPRISCAR are operating at multinational level all over the world. By increasing the size and scale of their international operations, these companies can take advantage of the economies of scale, due to these general standards.

With this reasoning in mind it is determined that also the market analysis for the VIPRISCAR technology should consider the trends and competition across the world. Nevertheless, a specific focus will be accorded to the European market as this is where VIPRISCAR will have the largest influence at an early, TRL 5, stage. Compared to the materials currently used, the raw materials for IBMC will be sourced locally. Decreasing the international scope of the value chain and the sourcing cost.

2.1.4 Timeline

Coating and adhesives have been a go-to solution for industrial application since the early 20th century (Morgan, 2002). Alternative products and production methods have been developed from a price/quality perspective over time. Nevertheless, it is anticipated that both coatings and adhesives will remain a major influencer in the industrial and biomedical (Catheters) fields. The market potential of VIPRISCAR does therefore not have an expiration date. There is, however, a large amount of research conducted in the field at this point in time. Close follow up of the technology beyond the proof of concept is therefore important at the end of VIPRISCAR to avoid delay in market uptake and ultimately obtain the first mover advantage. Based on this, the market analysis will consider a timeline of 10 years.

2.2 The value chain

2.2.1 The traditional value chain

Now that the target market is selected, it is important to analyse the value chain of this market in detail. This means, understanding the whole supply chain from raw materials all the way through to end customers (and the product's end-of-life purpose), by going through all suppliers and first, second or third tier customers and how these different players interact with one another.

The overall structure of the value chain of the different industries that are considered in this market are closely aligned. Because of this, a general value chain analysis is conducted and represented below. More details on the exact players and influencers in each market can be found in the benchmarking analysis of each industry in section 3.2.

Figure 4 gives a visual understanding from the flow of materials and added values that are operating in the traditional value chain of current coating, adhesives or catheter production. Each section is explained in detail below. The highly linear model shows the limited opportunity for existing products to be recycled because of the toxicity and non-degradable aspect of the adhesives, coatings or catheters. The impact that VIPRISCAR will have on this value chain will be highlighted later on in Figure 7: VIPRISCAR value chain.

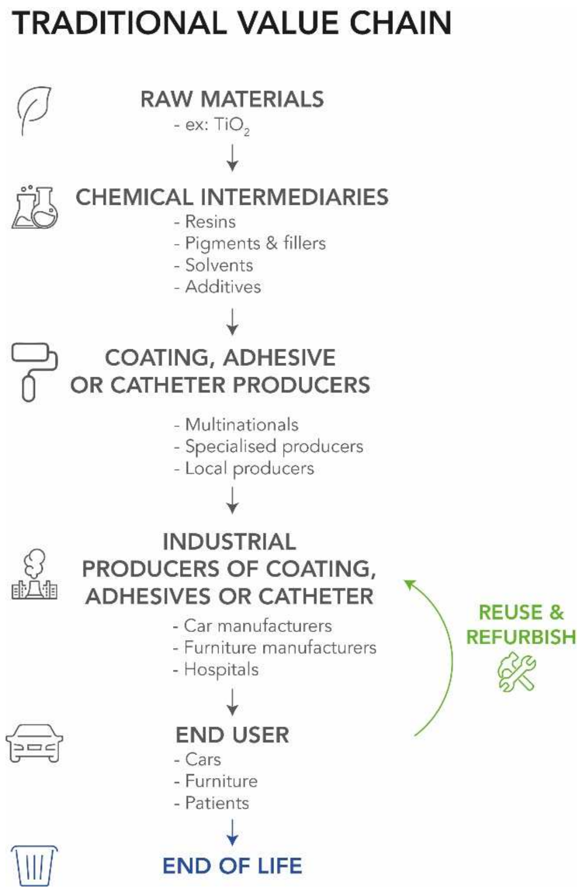


FIGURE 4: TRADITIONAL VALUE CHAIN

2.2.1.1 Raw materials:

Raw materials represent for these industries an important part of the overall cost of production. For coatings specifically, this comes down to almost 50% of the all costs (Chemquest, 2018). Adding up to a total market value of €51.19 billion for 34.3 million tons of materials (ChemQuest, 2018).

The materials used for coating or adhesives also serve as input for other products such as plastics, personal care products or water treatment. This wide demand puts a lot of pressure on the suppliers of the raw materials and creates a competitive environment. Particularly in 2017 and 2018 there has been a scarcity of raw materials supplies, leading to price peaks (ChemQuest, 2018).

2.2.1.2 Chemical intermediates

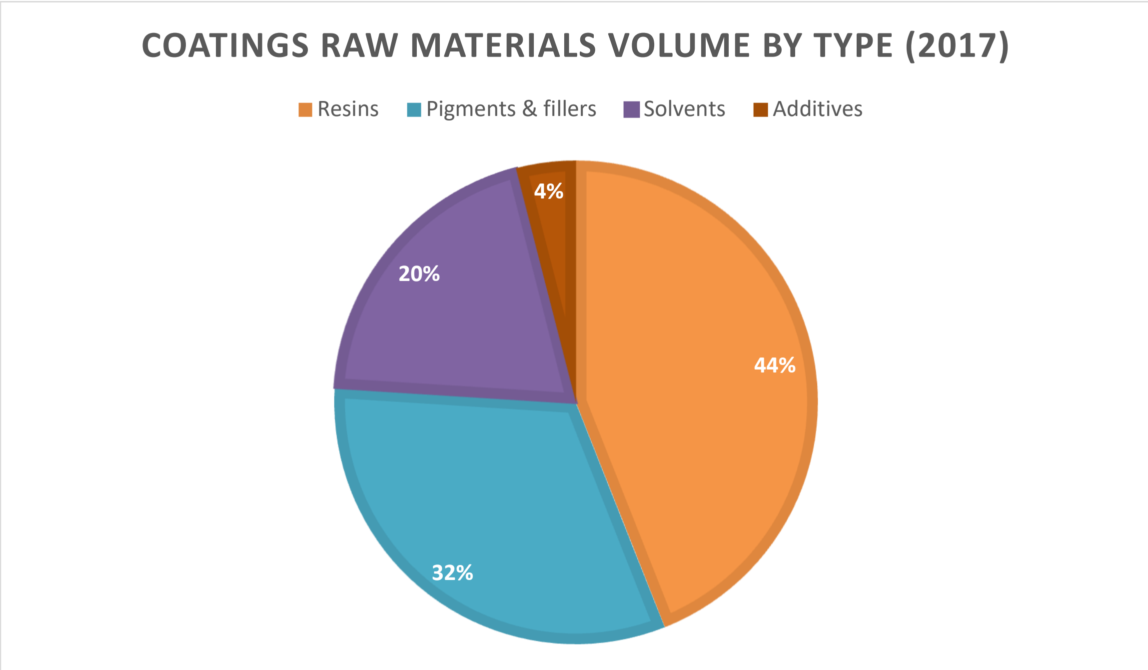


FIGURE 5: COATINGS RAW MATERIALS VOLUME BY TYPE (2017).
SOURCE: *(CHEMQUEST, 2018)*

For this chapter of the value chain, the study will consider in detail the example of coatings. Traditionally the chemical intermediates required for coating includes additives (4%), solvents (20%), pigments & fillers (32%) and resins (44%)(see Figure 5) (ChemQuest, 2018).

The resins market alone is estimated to have a global worth of $25 billion, for a production volume of 15.2 million metric ton (ChemQuest, 2018). Within the resins sector, different types exist and compete with one another, depending on the application area. Today, the most common resin in coatings and paint sector is Acrylic. Acrylic accounts for 27% of all resins used. The resin is however very susceptible for price changes.

A second common type for resin is alkyds (20%). This resin however is increasingly debated in Europe and America, as the EU and American volatile organic compounds (VOC) limits keep dropping (ChemQuest, 2018). Because of this, there is in this sector as well intensive research being conducted to have a more health and environmentally friendly production method, such as water based alkyds (ChemQuest, 2018).

Other commonly used materials in the coatings production for resin include epoxy (16%), or amino, polyester, vinyl, etc.

Next to resins, the second most represented raw material in the coatings are the pigments. This material represents a market value of €13.3 billion for a total volume of 11 million metric tons. The importance of this material is depending on the colour required and the importance of it in the end product. The proof of concept of VIPRISCAR will be applied mainly in furniture or automotive sector, two sectors where the colour is deemed important. It is therefore an advantage that previous research has shown that isosorbide polycarbonates are conveniently mixed with pigments. Within colours there are either organic or inorganic colour pigments. Organic pigments today represent only a small share of the total market yet (about 20%) mainly because there is still a significant price difference (Chemquest, 2018). To improve the environmental impact of the coatings on an overall level, the selection of organic colour pigments should be considered.

The third key component to the product is the solvent. This market separately is worth €6,45 billion with a volume of 6,5 million metric tons. The material is currently undergoing a phase of research and development as it is the main contributor to the volatile organic content in coatings. Because of this there is a downward trend in the material consumption across the world. Simultaneously however, the products that require these solvents, beyond coatings, have seen an increase in consumption, averaging out the total volume of solvents to a stable level. (ChemQuest, 2018).The IBMC that will be developed in VIPRISCAR uses organic solvent mixed with water for the synthesis. After this the solvent will be distilled off. The target set for the lab scale process is to recover 70% of the solvent. The coating developed during the project will be solvent-free or contain water as a solvent, therefore the potential market uptake of IBMC will reduce the solvent market size.

The final input in the coating are the additives. These account for 4% and can include anything such as plasticizers, biocides, foam control additives or flatting aids. The types required and the environmental impact of each of them will depend on the end user of the coating.

The competitive landscape of these materials can have a significant impact in the pricing and competitiveness of the coatings produced. There are 3 types of competitors in the industry. First of all, there are the multinational chemical companies that operate across the world in many different types of chemicals. Key players here include BASF, DOW/Dupont or Eastman Chemical. These companies represent the largest share of the market. Nevertheless, there are competing companies that have established their name in the market. These are multinational product specialists, such as Reichhold for resins, or Cathay for pigment. Their operations are specialized on a limited product offering but across the whole world. Finally, a third type of competitor are the local or regional suppliers. Although the market share dedicated to this third type is smaller than any other, the companies can sometimes achieve a competitive price compared to the SMEs thanks to their lower overhead cost of operating in a single specialized location, compared to the entire world.

2.2.1.3 Coatings, adhesives or catheter producers

The industrial producers in the industries studied have a similar competitive structure as the chemical intermediaries, namely, multinational companies, multinational specialized producers and local companies. The characteristics of the products might have slight variations depending on each end manufacturer. Continuing with the example of coating, the different sizes of producing companies will serve different segments of the overall coating industry. Overall there are 3 main market segments of types of coatings: architectural, industrial and special purpose.

Architectural coating has seen a high increase in positive grown the past year. In the US alone, this market is worth a total of $11.8 billion, through an increase in price combined with an increase in volume. This high growth that the industry has experienced over the past 10 years results from, amongst other trends, an increase in single-family home constructions and ownership (Chemquest, 2018). Architectural coating usually represents the largest segments of all coating types.

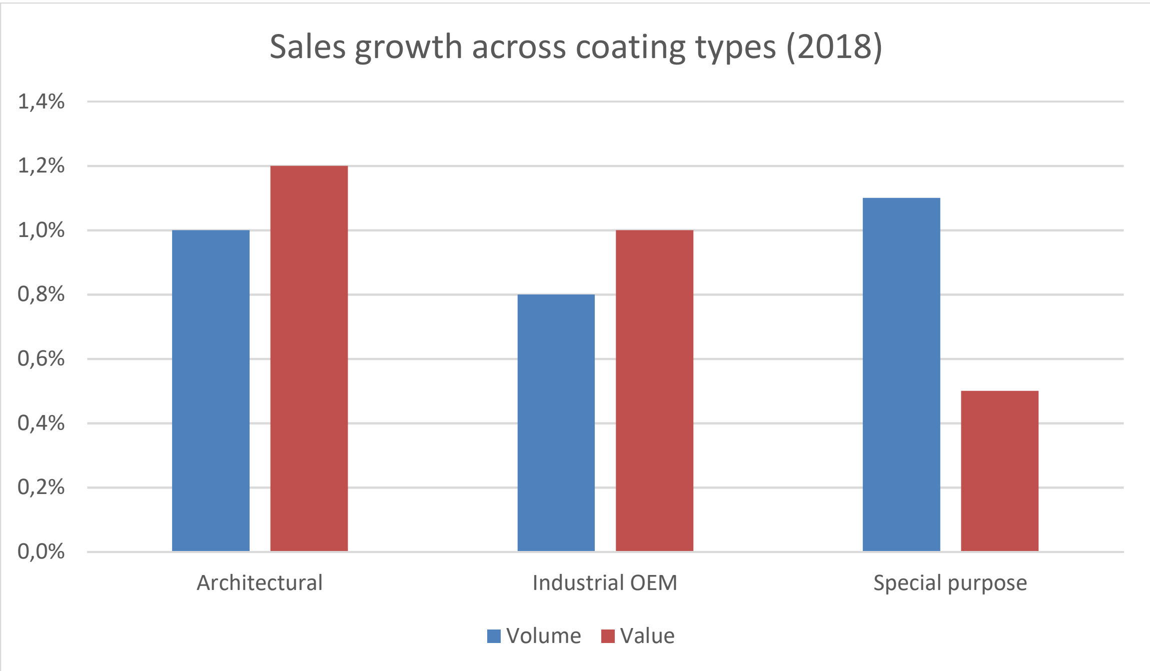


FIGURE 6: SALES GROWTH ACROSS COATING TYPES (2018)
SOURCE: *(CHEMQUEST, 2018)*

Multinational companies, such as PPG, SHW, or Akzo Nobel choose to produce all 3 types of coatings. This diversity made them the 3 largest coating producers with combined more than 25% of the total market share (Chemquest, 2018). Other more specialised producers will choose to serve only one or two segments of the total market.

2.2.1.4 Industrial coating, adhesives or catheter users:

The product developed by the chemical companies and the producers is sold to the industrial client. The relationship between the direct client and the supplier is often on a long-term contract basis. At most instances this client has previously passed on the requirements of the exact characteristics before production started. Therefore, the industry is set to be able to adopt a 'just-in-time' production strategy (Coatings World, 2018). Depending on the application area, different requirements will be determined. For the automotive industry for example, different level of coatings will have different requirements based on colour, density, resistance, etc. Each coating type can be requested by the same company or can be source from different firms.

2.2.1.5 End client

Coating is often the last stage of the production chain of the industrial partner. Adhesives as well, are part of the final assembly stages of the production process. After this, the product is passed to the end client. Depending on the product in question, this is the end of the value chain. Potentially, there might be an intermediate renewal of the coating and painting layer, for example with cars, but this is a small segment, unrepresentative of the market and its evolution.

When the end client is ready to dispose of the product, after a single use, such as with catheters, or after years of use, like with cars, the products have reached their end of life. In the traditional value chain, and the traditional raw materials used, make it difficult to recycle. Commonly, products that use coatings or adhesives, such as cars, can be refurbished or reused and given a second life. The majority however will be sent to land fill and be considered as waste.

2.2.2 Value chain VIPRISCAR

The VIPRISCAR research on IBMC and the use of it in coatings, adhesives or catheters can alter the value chain significantly. The figure below shows the new order of events and highlights the shifts towards circularity.

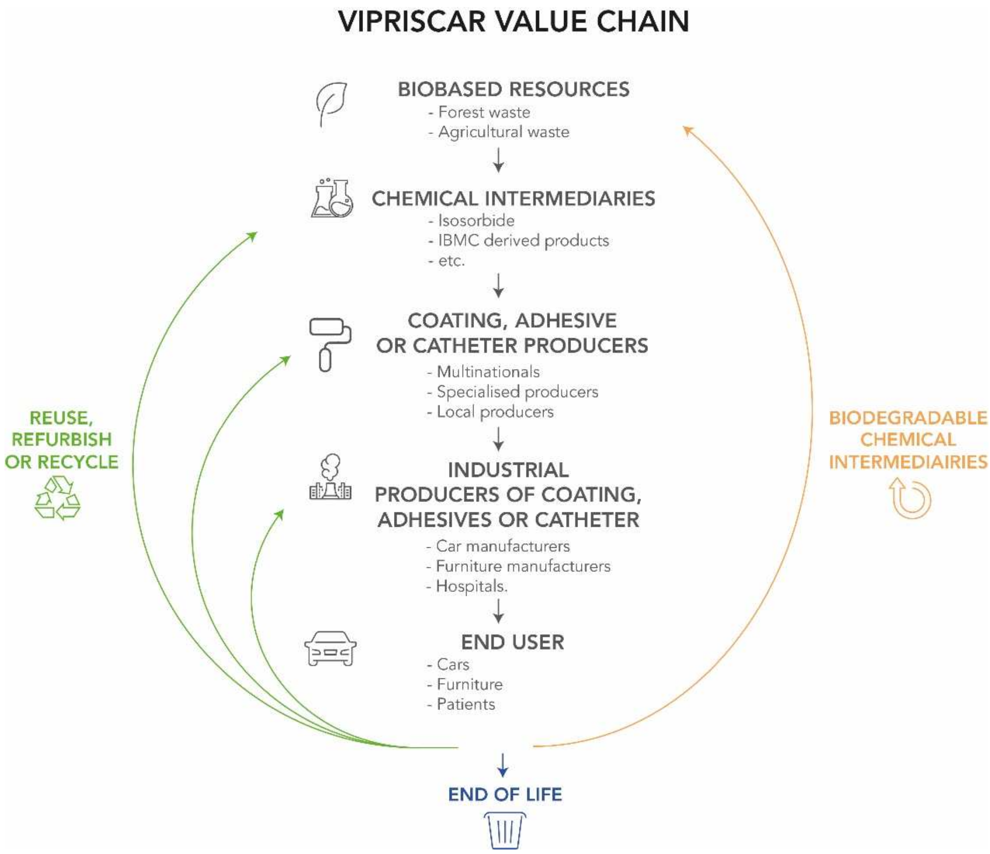


FIGURE 7: VIPRISCAR VALUE CHAIN

2.2.2.1 Bio-based raw materials

Biomass resources is the term that refers to all materials that directly result from organic matter. This can result from different sources such as wood based, agricultural crop, algae or municipal waste (Energy.gov, 2019). At this point in time the key biomass resource that is used to produce Isosorbide is glucose extracted from corn starch. In total the industry produced 11.8 million tons of glucose in 2016 (Eurostat, 2017).

Suppliers that provide the corn based glucose in Europe are, amongst others, Avebe, Saint Louis Sucre, Grain processing corporation or Roquette Freres (Marketline, 2018b). The European market is led by Roquette Freres, a family owned company producing corn starch and starch derivatives. Based on the natural resources the chemical intermediate products, that are required for coatings, can be produced.

2.2.2.2 Chemical intermediaries

The technology developed in VIPRISCAR will mainly influence the resins intermediates, the largest component of the coatings overall. As was mentioned in the traditional analysis, there is increasing research to develop environmentally friendly resins. Because of this reason, Polyurethane resin is increasingly popular in the industrial applications. For this resin the VOC level can be controlled at a lower level. The specific innovation that is looked at in the VIPRSISCAR project falls under this type of resin. The research looks at, just like numerous other research projects now, polyurethane water-borne dispersions (PUD). These are created form single component coatings that are more resistant than the waterborne acrylics, currently under development. Overall urethane resins currently represent about 21% of the resin market for coatings (ChemQuest, 2018).

2.2.2.3 Coatings, adhesives or catheter producers:

The producers of coatings and adhesives or catheters will realise limited process changes when shifting from the traditional value chain to the VIPRISCAR product. The competitive landscape, including the multinationals, specialised producers or local producers, will decide on the overall market uptake of VIPRISCAR. Since the shift towards VIPRISCAR technologies will require limited fixed cost expenses, such as altering production lines or health and safety regulations, for the final users, it can be easily adopted across all market players. The impact of NIPUs on the supply chain will need to be studied further, to calculate its effects on the production process.

2.2.2.4 Industrial users of coatings, adhesives or catheters

The choice made by the producers of shifting to VIPRISCAR will have no negative effect for the industrial users. As explained in the technical description (see P.12) the effect will only enable a wider use of certain materials in certain application areas, such as resistance to UV exposure (VIPRISCAR, 2017).

2.2.2.5 End users

The end user will most probably not realise the differences either. Only a very conscious buyer that is concerned about the end of life of each individual part of the product will actively look for the differences and purchase responsibly.

2.2.2.6 End of life

A large impact of shifting to VIPRISCAR product on the value chain will happen at the end of life stage. The novel materials used as raw materials for the 3 products will facilitate the recycling process of the final products created. The cars or furniture can therefore be refurbished, reused or recycled. Part of the recycling however will always include a certain level of downcycling. But contradictory to the traditional value chain, when no more recycling is possible the chemical intermediaries are biodegradable. A piece of wooden furniture thus becomes completely biodegradable and no adhesives or coatings will pollute the soil.

3. Market analysis

Based on the understanding of the market and how it operates along the value chain, the in-depth market analysis can be conducted. This will consist of different sections. First of all, the PESTEL analysis will be conducted. This is a common analysis for all three industries, adhesives, coatings, and catheters. The general PESTEL will influence the industry specific analysis that will be conducted afterwards. This specific study will contain a benchmarking and a market sizing.

3.1 PESTEL

The PESTEL analysis is a market research methodology that was introduced by Michael Porter in 1980 (Porter, 1998). The acronym refers to a market analysis on the current and future trends from 6 angles that can significantly impact business as usual. The 6 perspectives are Politics, Economics, Social, Technical, Environmental and Legal.

Based on the academic and business literature that was conducted for the previous parts of this study an initial understanding can be formed within each sector. It is important however to go more in depth and identify the key trigger points.

For the purpose of this paper the PESTEL analysis focuses on all three application areas. This approach was selected as most of the influencing factors will have a direct or indirect impact on more than one of the studied industries. Alternatively, some key points might be specific to one sector but will still be discussed in the common analysis that follows below.

3.1.1 Political

- **BREXIT**: Currently the UK is a net exporter and large internal consumer of coatings and adhesives (European coatings, 2019). The British Coating Federation, however, prepares for a possible loss of £1 million in this field, as a result of the BREXIT. Depending on the deal that will be implemented, the export from the UK to Europe of coatings and adhesives, or its application areas, such as automotive, might be blocked through high tariffs and restrictions on the raw materials and end products it interacts with (European coatings, 2019). Current Brexit deadline has been extended to latest, October 31st, 2019 (Elgot, 2019). It is suggested to keep a continuous eye on the matter to prepare the strategy accordingly in advance.
- **Tax reduction on adhesives and coatings:** increasingly, trade agreements across regions have been on a trend reducing the tax for coating and adhesives import. The trend is expected to continue and allow for facilitated international trade. This will impact the potential of European firms to internationalize, but also the potential for international firms to come in the market and compete locally (European commission, 2019).

3.1.2 Economical

- **GDP growth:** For a general, overall understanding of the evolution of the coatings and adhesives market it is sufficient to consider the GDP growth rate of a country and a region. The Gross Domestic Product of a country is the measure of the market in monetary value of all final goods and services that are produced (for local consumption or export) within this country. Both industrial coating and hot melt adhesives are present in most items of the daily life. Either as intermediate product for product assembly, or as coating to protect the final product, reaching from packaging, to textile or automotive sectors. As the economic development of a country increases the GDP, and thus the consumption of these everyday products, the need for coating and adhesives increases in a parallel fashion (William Blair, 2017).

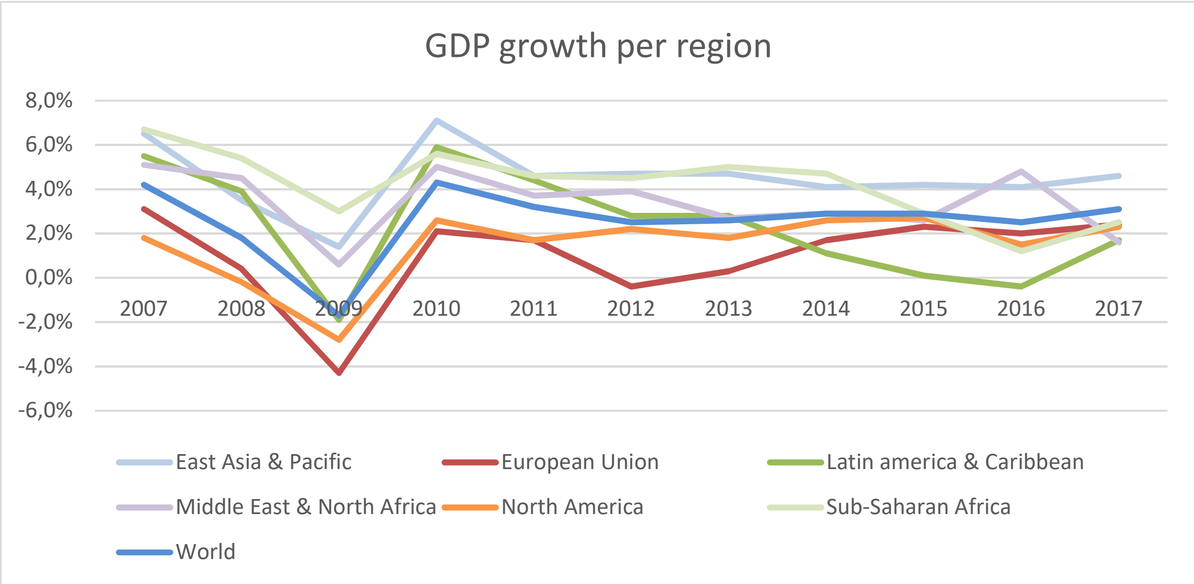


FIGURE 8: GDP GROWTH PER REGION (ANNUAL %)
SOURCE: *(THE WORLD BANK, 2018)*

The graph above shows the GDP growth rate (Annual %) across the world since 2007 (The world bank, 2018). Highlighted in orange is the economic growth of North America. To highlight the interrelation between adhesives or coatings Figure 9 below shows the sales volume and value of North America for adhesives. The particular focus on the impact of the global economic crisis of 2008 on the adhesives market marks the impact of GDP on adhesives production and sales. A similar trend, parallel to the red trend on Figure 8, could be expected for the sales figures in Europe, the main geographic focus for the first years of the VIPRISCAR material introduction.

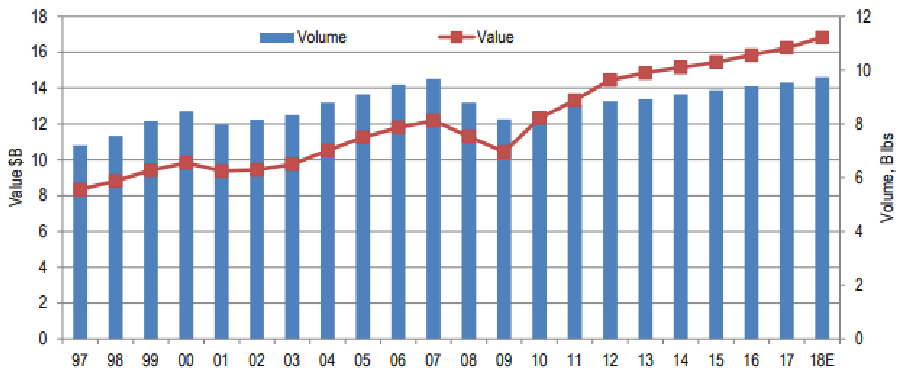


FIGURE 9: NORTH AMERICA ADHESIVES INDUSTRY 1997- 2018
SOURCE: *(CHEMQUEST, 2018)*

The European Union also suffered significantly from the global economic crisis in 2008 with a negative growth rate of 4% in 2009. Since then the GDP has been growing steadily with an average capacity of 1.5%. The growth rate in 2018 (2.1%) was again lower than the one in 2017 (2.4%) and this is expected to decrease further in 2019 (1.9%) (European Commission, 2018). This decrease in growth is expected to have a similar effect on the decreasing growth rate of hot melt adhesives and industrial coating production and sales. Most particularly this economic slowdown in Europe is expected to mainly affect construction, automobiles and machinery, as a result of faltering capital investment. These sectors are overall the main users of coatings and adhesives and will thus have a significant negative impact (Milmo, 2019). Asia is the strongest growing market for both overall GDP growth and hot melt adhesives and industrial coatings. But even here, alternative factors, such as environmental regulation, that will be discussed later, will slow down the growth in this region (Bohn, 2018).

3.1.3 Social

Beyond the economic development of a region there are other factors that can further influence the growth of the adhesives, coatings and catheters market. GDP is a general indicator but looking in more detail is crucial to understand what guides these changes. One aspect of this are the demographic changes.

- **Internet purchasing:** E-commerce has significantly increased over the past decade and is expected to grow further, up to a total value of US$4.9 billion by 2021 (Garcia, 2018). Indirectly this change in human purchasing behaviour affects the adhesives market. This is because the majority of these items are delivered in cardboard and paper packaging, materials that require adhesives in the production or sealing process (Chemquest, 2018).

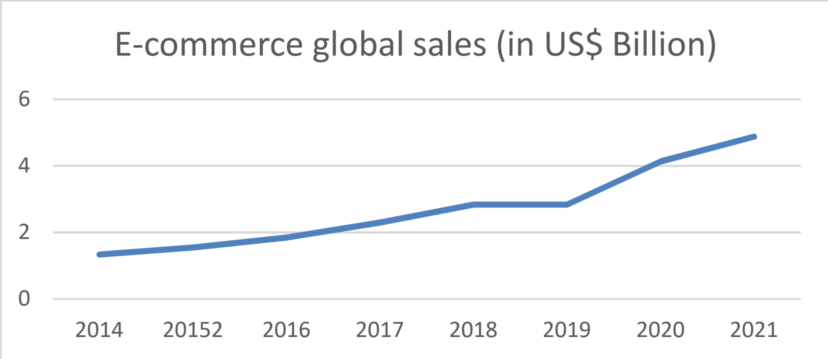


FIGURE 10: GLOBAL E-COMMERCE SALES VALUE (IN US$ BILLION)
SOURCE: *(GARCIA, 2018)*

- **Aging population:** Increasingly the population is getting older. The graph below (Figure 11) highlights that this problem is particularly prevalent in Europe. The population above the age of 64 years old is expected to increase from 18% to 28% of the entire population. This will have significant economic effects on the economy as a whole. But indirectly increases the demand for coatings. Particularly for biomedical coatings for catheters. As described below, catheters are commonly used for cardiovascular diseases. Older age is a known factor that increases the risk to cardiovascular diseases (Dhingra & Vasan, 2012).

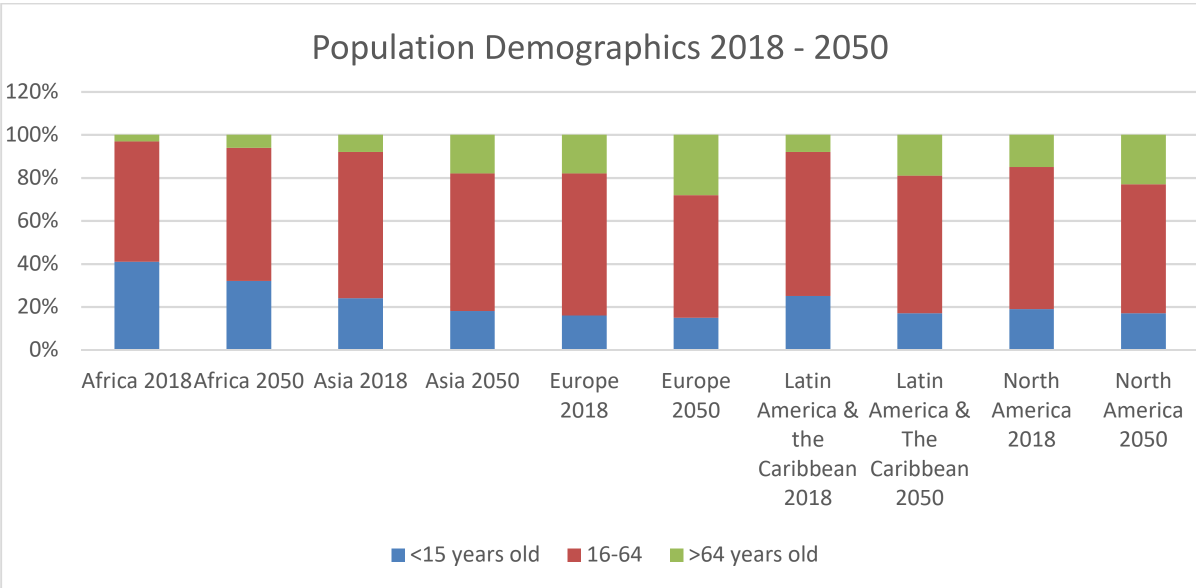


FIGURE 11: POPULATION DEMOGRAPHICS PER REGION 2018-2050
SOURCE: *(DSW, 2018)*.

- **Urbanization:** Worldwide 55% of the population lives in urban areas in 2018. This is an all-time high and is expected to increase further over the coming years. The most important region contribution to this global trend is Asia, countries like China and India where the percentage of urban population is expected to surpass the percentage of the rural population in the years to come (United Nations Population Division, 2018). Particularly in these regions this large urbanization trend will translate into an increased network of public transport and an increase in construction for accommodation or office purposes. In most European countries this migration to cities happened a long time ago and there will be thus no significant impact of this continuous growth on the adhesives industry.

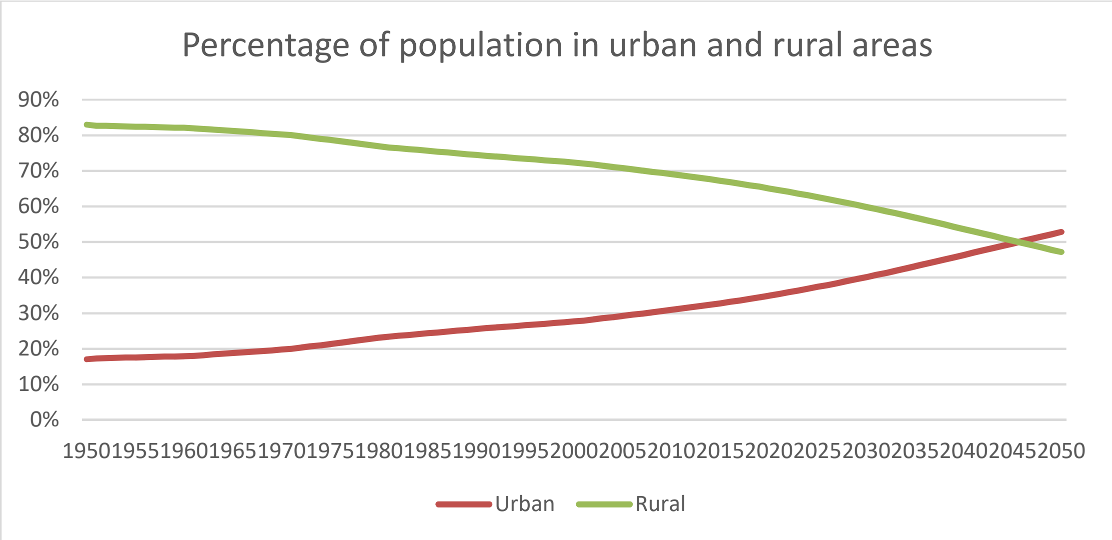


FIGURE 12: PERCENTAGE OF POPULATION IN URBAN AND RURAL AREAS IN INDIA
SOURCE: *(UNITED NATIONS POPULATION DIVISION, 2018)*

- **Quality of life & economic development.** Consumption of adhesives and coatings per capita is linked to the stage of economic development of a country or a region. When looking at the average consumption per capita (see Figure 13), there is a clear increase in consumption of adhesive related products when the GDP increases (Chemquest, 2018).

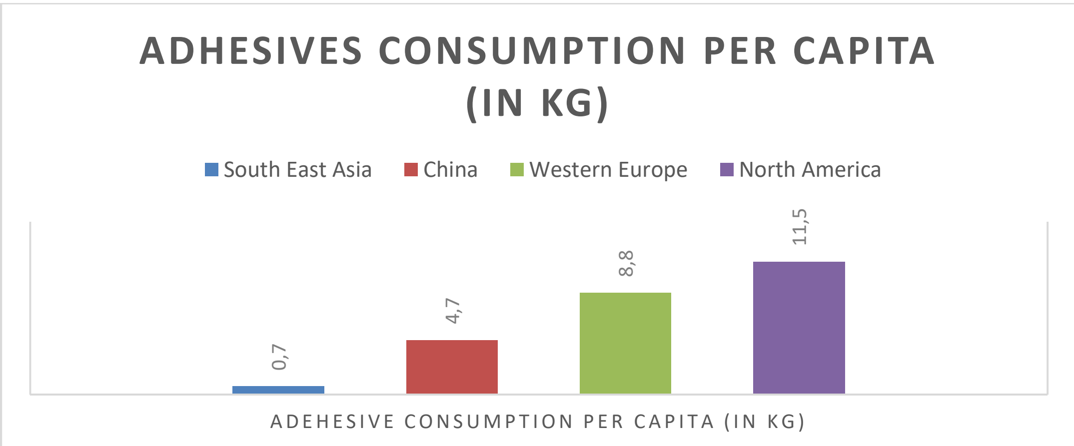


FIGURE 13: ADHESIVES CONSUMPTION PER CAPITA (IN KG)
SOURCE: *(LEGROS, 2017)*

- **Individualization of society**: Increasingly the European society is moving towards individualization. The share of European single-person households has increased from 13.0% in 2007 to 14.7% 10 years later (Eurostat, 2019a). This trend and the increasing fast paced lifestyle go hand in hand with a significantly larger amount of disposable packaging for single use items. During this same period, packaging waste increased by 6% (Eurostat, 2019b). This increase in packaging consumption translates into an increase in adhesives demand. Nevertheless, other social and environmental incoming trends might alter this growth rate, for the interest of the environment.
- **Environmental awareness**: As will be discussed in more details in the 'Environmental' section of the PESTEL analysis, the increasing pressure to take care of the planet will significantly impact business as usual over the coming years. One area of impact will be the change in consumer behaviour. Examples for this are the following:
  - **Car sharing**: Car sharing is the increasingly popular business model that provides cars that can be rented for a short or longer period of time. The model is particularly focused on metropolitan cities where it is not economically interesting to own a car as an individual. Numerous examples of this are popping up across Europe, including Car2go, Drivy or Ubeeqo or variations of the model such as Uber or Taxify. The impact of this trend to the coating market is twofold. First of all, the goal of car sharing is to reduce the number of cars in the city. Achieving this goal means a decrease in cars purchased and thus a decrease in required coating. On the other hand, a second goal of the carsharing model is to increase the usage time of a car. Currently cars are on average, parked 95% of time (Morris, 2016). Car sharing might reduce the number of cars but will increase the usage. This means the wear and tear of the coating will go faster (Nishigami, 2019). To tackle this, a large amount of research is conducted to improve the quality and resistance of the coatings used for automotive.
  - **Recycling**: Over the past decade, the general public is increasingly aware of the importance of recycling in the daily life. For paper and cardboard packaging, the European recycling rate has now reached 85.8% (Packaging Europe, 2019) . This is the largest percentage of any recycled material. This increase will possibly affect the quantity of adhesives required in this sector but represents an opportunity for increased quality and biodegradability.

3.1.4 Technical

Technical innovations of competing products or substitutes can significantly impact the market uptake of the VIPRISCAR research. Complementary technological innovations can enhance the demand and interest in IBMC technology. When technologies are too similar however, the first mover advantage of the competitor might block any uptake potential for this solution. Below is a list of technological micro and macro incoming trends that will influence the market growth.

- **From welding to adhesives**: Despite of the economic slowdown, and the impact this has on transportation and construction markets in Europe, the industry can still see significant growth through technical innovations that alter the production methods of particular items. An example of this is the shift towards adhesive bonding in major industries, such as automotive. Traditionally certain joining processes would be conducted though welding or mechanical fastening, but now prefer adhesives (ASI, 2019).
- **Environmental pressure:** Just like the environmental pressure implies a change in the social behaviour of the consumers, it also affects technology today. Research is increasingly directed to sustainable solutions with a reduced environmental impact. Amongst others, this pressure is the reason for the following technical trends:
    - **Electrical vehicles**: Electric Vehicles were for a long time seen as ‘good for the environment but low on performance and aesthetics ‘ (Statista, 2019b). Thanks to Tesla however this perception is changing, and electrical vehicles are no longer only reserved for people who only care about the environment. Since 2008 the share of EV on the road has been increasing significantly, and not only through Tesla cars. An increase in these cars sales will give a novel push to the coatings market. At the same time, Tesla is also a leading player in the field of autonomous cars. This incoming trend is offering opportunity for coating manufacturers to provide coatings with enhanced autonomous vehicle detection material (CoatingsWorld, 2019).

3.1.5 Environmental

It has been mentioned before in the market analysis that the environment is putting a higher pressure than ever on the type of products that are consumed and the process method that it requires. The VIPRISCAR technology of IBMC derived PCs or NIPUs falls in line with these progressively stricter environmental and safety requirements. Overall this can thus be recognized as the single most influential trend in the field today. In more detail this pressure translates into the following changes:

- **Volatile Organic Compounds (VOC) requirements:** VOC are organic materials of which the use results in the evaporation of certain molecules which can be harmful to the environment. The use of these materials is increasingly contested and debated in North America and the EU, leading to restriction of the VOC level in, amongst other products, resins for coatings and adhesives (ChemQuest, 2018). These limitations have opened opportunities for water-based polyurethane coatings as they can be formulated with a lower VOC level (William Blair, 2017). With this in mind, VIPRISCAR IBMC based polyurethane will fit with the current and incoming environmental trends.
- **Asian market slowdown:** The Indian and Indonesian coating markets are bypassing the historical leader, China. This slowdown of the market growth is related to general decrease of GDP growth in China but for coating and adhesives this particularly results from increase in environmental regulations. The VOC requirements and taxes have been introduced here

as well and even the emissions resulting from the paint producing plants are controlled today (Olson, 2016) (Bohn, 2018). This regulation decreases the competitiveness of many local players and increases the international incoming competition.

- **Bio-based based coating**: These regulations have already proven impactful in the European coating industry where bio-based coatings have seen a significant increase in research and production. In 2019, the total volume of bio-based materials for coating in Europe is estimated at over 1 million tonnes (Veneman, 2019). Another proof of the increased environmental awareness is the percentage of market share of the coatings market that is obtained by water-based coatings (Coatings World, 2017).

3.1.6 Legal

The legal framework supporting the coating and adhesives industries, are highly influential in the field. Legal boundaries are either a precedent or a result of another macroeconomic trend that is gaining attention. Like in most occasions, the legal boundaries in the coating, adhesive and catheter industry is a result of both existing and incoming trends.

- **Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH):** The REACH regulation was introduced in the EU in 2007. The aim is to improve the protection of human health and the environment from the risks that can be posed by chemicals (ECHA, 2019). REACH introduces procedures in the European market for collection of information and assessment of hazardous substances. After this information is evaluated and within the manageable risk requirements the product can be introduced in the market. The program considers all items that at some point come through the chemical sector. This makes IBMC derived PCs and NIPUs an important segment. After 10 years of introduction all products in the market comply. Nevertheless, the REACH requirements becoming increasingly strict, which demands constant monitoring (European Commission, 2019)
- **International standards:** The impact of REACH also translates into the in the adoption of this assessment process in other regions. An example of this is the United States, Canada and Mexican agreement. In response to REACH, 9000 chemicals locally produced or imported are assessed. By 2020 each of these countries need to have inventoried all chemicals that are in use in the market (Black, 2008).
- **FEICA**: Additional guidance exists for the adhesive sector, under FEICA, the Association of the European adhesive and sealant industry. This body aims to align European legislators with industry players, while promoting a sustainable, healthy and safe use of the products (FEICA, 2019).
- **Banned products:** Bisphenol A is an organic synthetic compound that is a core material for polycarbonates and epoxy resins for, amongst other things, plastics and catheters. In recent years however the danger level of the chemical product has been debated and is now listed as toxic and illegal for specific products in certain states in the US or countries in Europe

(OEHHA, 2015). An example of this is the EU-wide ban on Bisphenol A in plastic baby bottles (BBC, 2010). The ban of the chemical promotes opportunity for VIPRISCAR research as the Isosorbide developed and increasingly popular in the field, can serve as an alternative to this Bisphenol A, making food contact with the derived polycarbonates possible. Another anticipated trend in the market is the ban on Isocyanate. Isocyanate is an organic compound that is commonly used in the production of foams, coatings or catheters. The toxicity level of this compound might soon no longer be accepted and thus banned for use in Europe and other markets. This potential ban opens the market for the VIPRISCAR non-isocyanate polyurethane coatings and adhesives (European Coatings, 2017).

- **Single use plastic:** In 2018 the European parliament voted to commit to ban single use plastic in Europe. Although this new legislation will only be enforced in 5 years and it is limited to balloon sticks, stirrers, cotton buds, straws and plates and cutlery, it could influence the large market of single use plastic in the healthcare sector. This sector includes catheters that are, for hygienic reasons, limited to single use. Anticipating a change in the healthcare consumption of plastic would be necessary and will force catheter producers to consider biodegradable biomedical coating that is used for catheters. The VIPRISCAR solutions would enable circularity for catheters (Nederland Circulair, 2018). Nevertheless it would reduce the total number of catheters required and produced
- **No clear global consensus:** Although the regulations around the VOC level, production plant emissions and ban on certain chemical products is increasingly common around the world, there is no clear global agreement as to what level is exempt and what is not. This is a challenge for multinational producers that might have to adapt their products to the regulations in different regions. (ChemQuest, 2018). The different regulations that operate in parallel with one another (REACH, FICA, CLP, EU-Biocide regulation, etc.) are responsible for a lot of overhead costs and inefficiency in the market (European Coatings, 2018).

The quantification based on all influencing factors identified in the six different categories generate the following summary table. Figure 14 plots the impact (positive or negative) against the likelihood of each influencer happening and impacting the partners of the consortium. Based on this summary table an informed strategy can be implemented (See 7.1, p.57 for consolidated table).

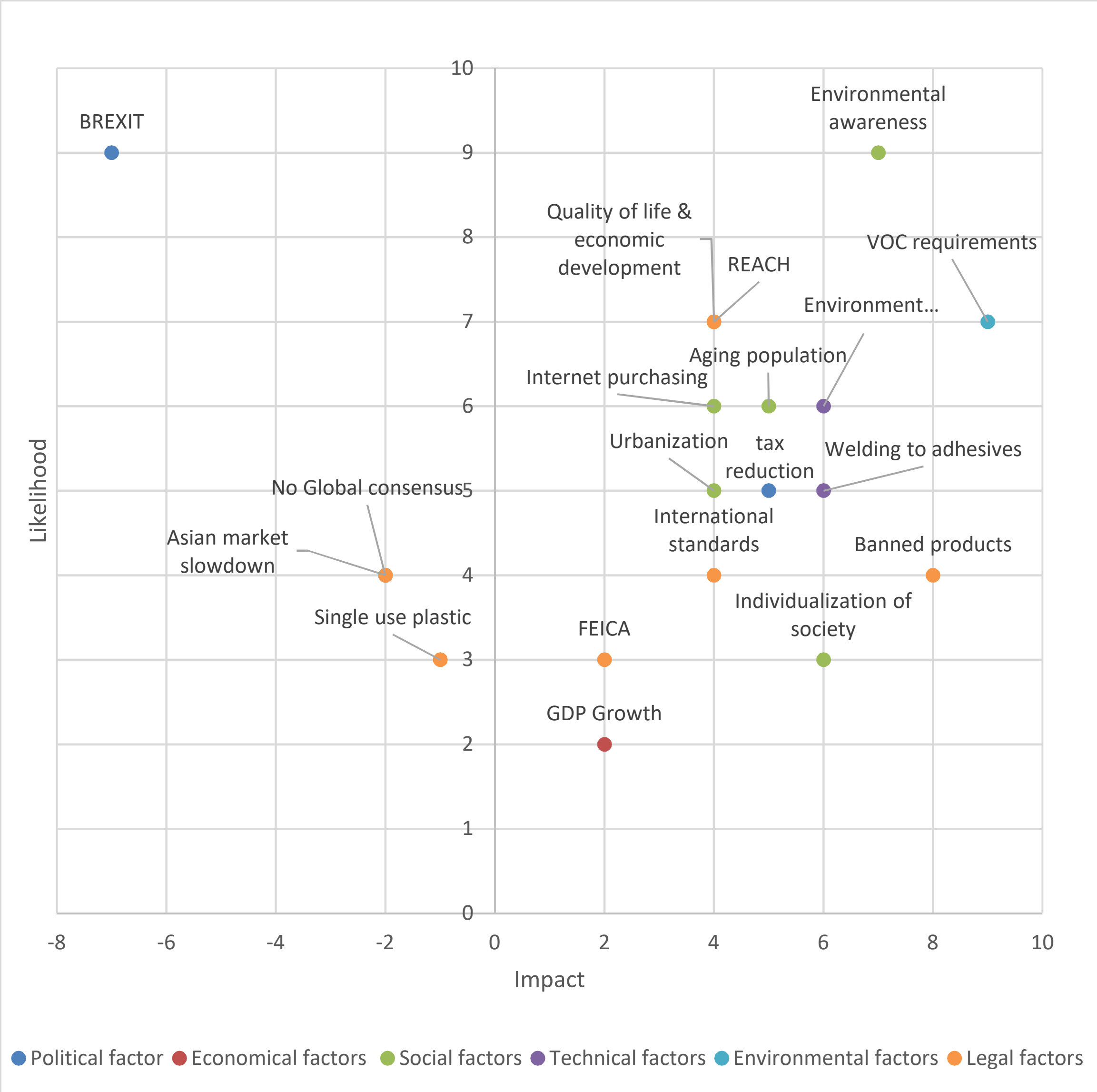


FIGURE 14: PESTEL ANALYSIS SUMMARY

3.2 Industry specific market aspects

3.2.1 Industrial Coatings

3.2.1.1 BENCHMARKING

To understand the product, its value and the competitors in a complete manner, a benchmarking study is conducted. This will help to later quantify the market in which it operates and the share of this market the innovation can obtain over the coming years. The benchmarking study will consider the current state of the art, the standards and the minimum requirements of the current solutions that exist. With the help of the key competitors identified, the study will be done primarily based on the understanding from the operations of those competitors.

Coatings production is an established but continuously improving process since the 20th century. The base ingredients include resins, solvents, additives and pigments. Of these items, resins represent almost 50% of the coating raw materials. This is also where the VIPRISCAR technology comes in. VIPRISCAR works on the development of IBMC derived polycarbonates-to synthesize non-isocyanate-polyurethane, that will serve as resin for the coatings production. However, polycarbonate or polyurethane coatings are not new. Their ability to use lower VOC, which is under increasing pressure (See PESTEL analysis:P.24), makes PCs and PUDs increasingly researched coating materials. This low VOC level is possible because polyurethane or polycarbonate resins can be dispersed using water as a solvent instead of traditional materials.

Currently, the state-of-the-art industrial coating includes isocyanate (Klein, 2019). The material has established itself as the standard for polyurethane because of its wide application opportunities (ASC, 2019). Even though the chemical reactions the isocyanate undergoes to produce polyurethane make the material harmless, exposure to the compounds prior is hazardous and can lead to significant health problems (Occupational Safety and Health Administration, 2019). The safety precautions that need to be taken in order to produce the polyurethane in a secure manner make the production process costly and slow (Kathalewar, Joshi, Sabnis, & Malshe, 2013). Furthermore, the increased pressure for 'green' materials is slowly making this state-of-the-art material outdated and opening opportunities for NIPUs. NIPU coating will possess a higher hydrolytic stability and chemical resistance compared to the traditional polyurethane produced coatings.

Several methods for NIPU production have been researched since 1955 (Kathalewar et al., 2013), but there are currently no markedly ready materials (Vertech Group, 2019).

Today, the market of polyurethane production is led by some multinational players that are leaders for the entire chemical production industry and operate across the world. The key players include BASF (Germany), Dow Chemicals (United States), Huntsman (United States), Bayer (Germany) and Yantai Wanhua (China). In total the 5 leading companies own over 35% of the total market share (Cornille, Auvergne, Figovsky, Boutevin, & Caillol, 2017).

FIGURE 15: BENCHMARKING OF INDUSTRIAL COATING PLAYERS ACROSS THE VALUE CHAIN

Because of their low VOC level, and high flexibility, polyurethane is increasingly becoming the standard material for industrial coating resin. Particularly for automotive OEM, industrial finishes and decorative coatings (ChemQuest, 2018). This industry is supplied by the chemical producers. The industrial coatings market itself is relatively fragmented with more than 100 players. Over time however it has become increasingly consolidated and the first 9 players currently own about 50% of the market. These players include PPG (United States), Akzo Nobel (The Netherlands), Sherwin Williams (United States), RPM (United States) and Nippon Paint (Japan) (Mcgarry, 2017; William Blair, 2017).

Looking into more detail at one of the companies, PPG, gives an insight as to the operations and trends between the competitors. In 2017, PPG reported a total revenue of $14,748 million. This was an increase of 3.3% compared to 2016. The total there are 47,200 PPG employees across 133 production hubs in 39 countries. The industrial coatings segment represents about 40% of their operations. In 2018 alone PPG acquired 3 smaller size coating producers and distributors, indicating the increasing consolidation of the market (Marketline, 2018a).

The figure below (Figure 16) highlights the key strengths and weaknesses of the state-of-the-art industrial coating production versus the VIPRISCAR technology under development. Based on the points where VIPRISCAR will stand out, the novel solution should be able to compete with the existing solutions. The scoring is semiquantitative. This means it is a relative scoring of one technology against the other. The choice of parameters and its weight accorded is based on the industrial requirements and the highlighted results from the PESTEL analysis.

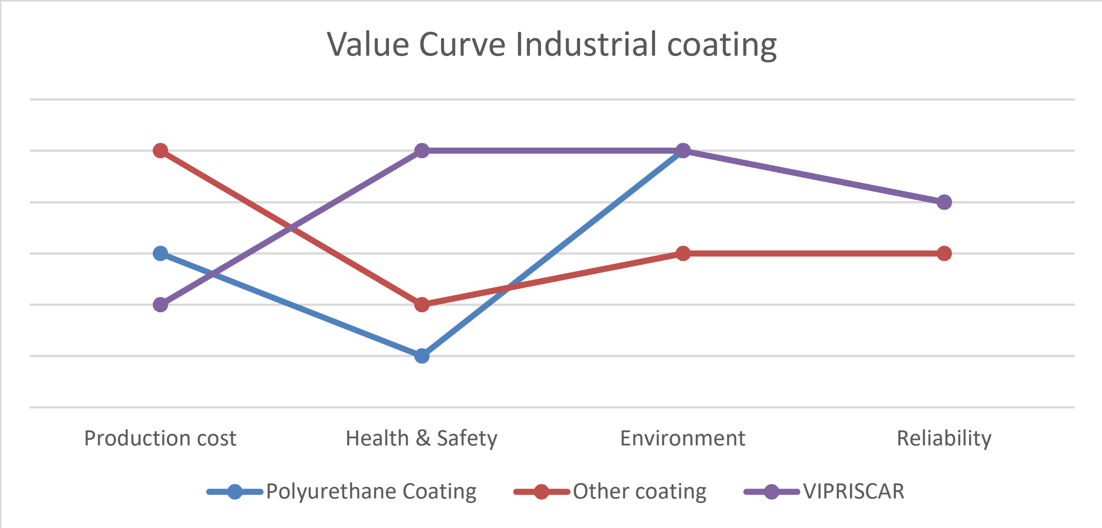
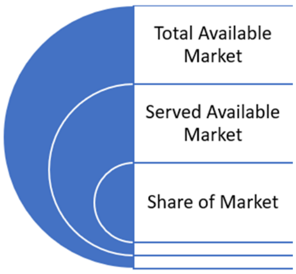


FIGURE 16: VALUE CURVE INDUSTRIAL COATING

3.2.1.2 Market size



The general industrial coating sector represents about 28% of the total paint and coatings industry (Mcgarry, 2017)The current value of this coating segment across the world was estimated at $74.913 million in 2016. Over the next 5 years this number is expected to grow at a compounded annual growth rate of 4.04% (2018 – 2023) (Mordor Intelligence, 2018). The main driver for this growth is the increasing awareness of the coating's impact on human health and the environment (see PESTEL analysis: P24) combined with the increasing adoption of polyurethane and polycarbonates as a resins material. This has seen a significant increase over the past 10 years. Growing from 4.2% market share in 2008 to an estimated share of 9.2% in 2021 for industrial coating (Coatings World, 2017). Different types of resin with waterborne finishes exist, including acrylic, alkyd, epoxy or polyurethane. Nevertheless, these solutions only improve the environmental impact but do not remove it.

Within this total available market of general industrial coating there is enough supply to serve the whole market. The multinationals competing with one another and acquiring the incoming competition makes it difficult for a new firm to enter and obtain a share of the market. However, with the existing patents it should be possible to obtain a significant market share once the technology is proven. The right strategy to exploit this market share will be developed when the technology is ready for scaling. The exploitation plan will be developed regularly throughout the project in preparation to this.

3.2.2 Hot melt Adhesives

3.2.2.1 Benchmarking:

Hot melt adhesives are the adhesives that become liquid when heated up to a certain point and solidify when cooled down. The IBMC that is under development in the VIPRISCAR project can be adapted to go through these phases and thus create hot melt adhesives.

Different polymers are at the core of different types of hot melt adhesive. These alterations in copolymers make a certain product fit a specific application area. The most commonly used copolymers include Ethylene Vinyl Acetate, polyolefins, polyamides and polyurethanes (Transparency Market research, 2018). Today, Ethylene Vinyl Acetate is still the leading copolymer in the market, but polyurethane is increasingly present. Polyurethane adhesives are particularly suitable for heat sensitive materials, as the melting point is reached at a relatively low temperature (Polymer Database, 2019). This makes the urethane a commonly used polymer for furniture, transport and packaging industry adhesives (see Figure 17).

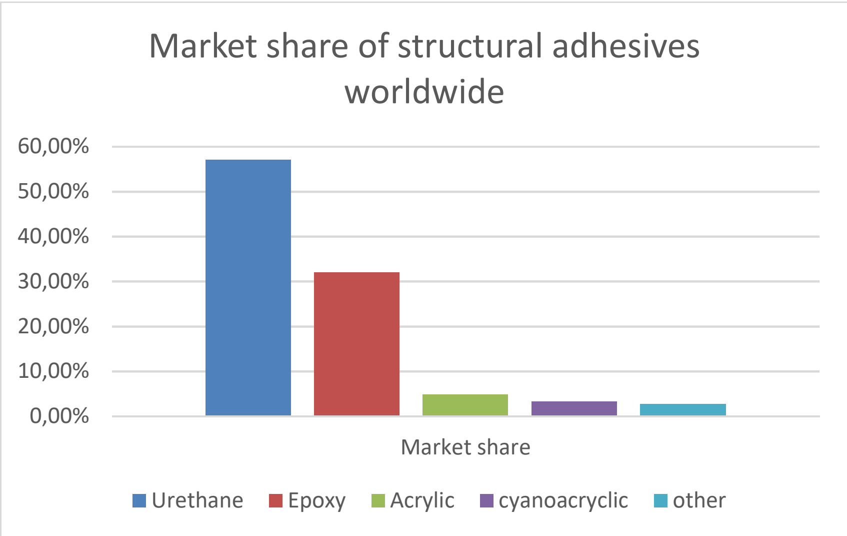


FIGURE 17: MARKET SHARE OF STRUCTURAL ADHESIVES WORLDWIDE IN 2016, BY PRODUCT TYPE.
SOURCE: *(BUSINESSWIRE, 2016)*

The polyurethane market is highly consolidated with a few global key players, including Covestor, Dow, BASF and Hunstman, amongst others (see Figure 18). The global PU industry is expected to grow at a CAGR of 4% between 2016 and 2021 (Covestro, 2017). Just like the coating and adhesive production plants, the polyurethane market is highly affected by the factors highlighted in the PESTEL analysis (see p24). This includes particularly, urbanization, population growth, digital revolution and a push for sustainability because of the resource depletion.

The same competitors and influencing factors count for the polycarbonate production market. This market as well expects a similar CAGR of 4% during the respective period. Which is due to the close link between polycarbonates, polyurethane and the global or national GDP because of the wide application areas the materials are applicable in (Covestro, 2017).

A drawback of the basic polyurethane is its relatively low resistance to UV lighting, which results in a fast decolouration of the material applied to (Polymer Database, 2019). Currently aliphatic isocyanate is used to go against this degradation. This goes with all the previously discussed drawbacks from the materials, such as the toxicity level that requires careful handling of this material. There is currently no commercially viable alternative to MDI (methylene diphenyl diisocyanate), TDI (Toluene diisocyanate), HDI (Hexamethylene diisocyanate) or other chemicals that can viably compete against Isocyanate, even considering the risks attached (FEICA, 2017). The introduction of IBMC can therefore be a strong competitor when entering this market by answering to an existing need and claiming the first mover advantage.

The value chain that is described in section 2.2, gives a good understanding of the role of different parties that are involved in adhesives production, including the future potential for end of life recycling. The graph below (Figure 18) is in addition to this, a straight-line value chain, describing the current linear model by which the industry is run. To understand the competitors at different levels of each step, a visual representation highlights the key players in the current market. These players will be important factors when considering the market potential and entry strategy for both IBMC derived polycarbonate and non-isocyanate polyurethane hot melt adhesives.

FIGURE 18: BENCHMARKING OF COMPETITORS ON DIFFERENT PARTS OF THE VALUE CHAIN
SOURCE: ***(COVESTRO, 2017)***

For the VIPRISCAR project and consortium partners, this paragraph will mainly focus on the monomer/isocyanate derivative producers in a first section, and later the adhesives makers. As can be seen in this section the players for industrial coatings and adhesives, and the polymer producers, can closely overlap one another since certain multinational firms have expanded their operations to gain a larger market share of the two markets that are closely linked to one another from a both a chemical and an industry perspective.

The adhesives makers market is highly consolidated, with the majority of the market share divided between 3M, Henkel and Dow Dupont (ASI, 2018). These companies are operating across the world and growing their position in each market over time through active merger and acquisition activities. In 2018 alone, Henkel acquired 3 new entities to strengthen their position in the Americas with investments in Peru, Chile and the USA (Henkel, 2017). These mergers or acquisitions are not necessarily directly in the adhesive industry but translates into a strategic market entry position for other business entities.

Next to M&A activities, the multinationals in the adhesive market still invest, on average, about 2.5 – 5% of the total revenue on new research and development activities. For Henkel, 58% (€273 million) of this budget was accorded to adhesives only (Henkel, 2017).

3.2.2.2 Market size

The global market size of hot melt adhesives is currently estimated at a total value of $6,480 million per year, equalling a total volume of 1,500 kt/year (Technavio, 2018). Because of different PESTEL factors the compound annual growth rate between 2017 and 2022 is estimated at 6.5%. Implying a market value of $9,455 million per annum by 2022 (Technavio, 2018). This strong growth rate and high value is due to the wide potential of application areas where hot melt adhesives play a competitive role. The glue can be used on different kind of materials and for different purposes, including furniture, packaging or transportation. Globally the automotive market is the largest end client for hot melt adhesives with about 25% of the market share (see Figure 19).

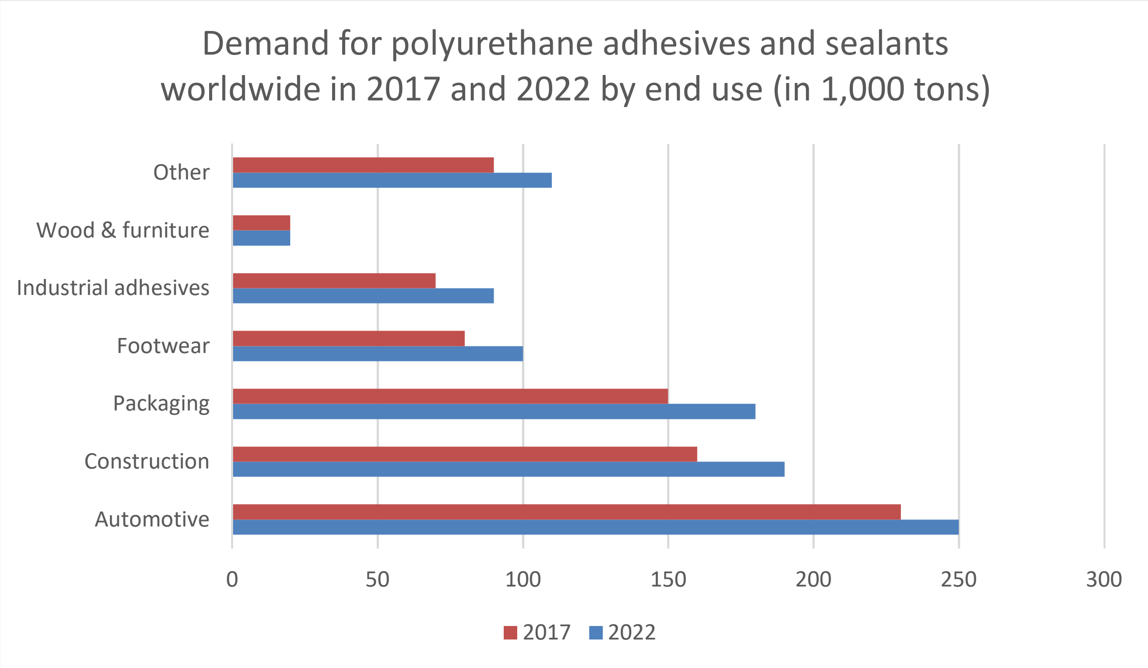


FIGURE 19: DEMAND FOR POLYURETHANE ADHESIVES AND SEALANTS WORLDWIDE
SOURCE: *(COVESTRO, 2018)*

In Europe alone however, the paper board and related products is the largest end-user sector amongst them. This market reflects about 20.3% of the entire adhesives market in Europe, equalling €2.9 billion on its own (Davies, 2017).

The porter's five forces (see P.43) later will highlight that all three industries studied for this project are dominated by multinational players. Just like for the industrial coating sector, the market share that can be obtained by VIPRISCAR will rely on the patents and market demand for change. Jowat is a significant player in the adhesive market and can exploit the unique, first mover advantage to grow exponentially.
Leading players and patents part of the consortium. As part of the consortium this growth will be transmitted to all industrial partners.

3.2.3 Catheters

3.2.3.1 Benchmarking

Catheters can be made from different materials, each one highlighting different advantages and drawbacks such as flexibility, biocompatibility and durability. The common materials include silicone, polyvinylchloride (PVC), nylon or polyurethane. Compared to silicone, polyurethane is more durable and less porous. As a thermoplastic the polyurethane catheters soften when heated and become more rigid when cooled down. Because of this characteristic the catheter will soften when inserted in the body. Furthermore, the thermoplastic allows the walls of the catheter to be thinner, enabling a larger diameter and smaller chance of clogging compared to silicone catheters. Nevertheless many researchers prefer silicone catheters due to their smaller risk to cause injuries to the vessels due to their lower rigidity at the cold stage (SAI, 2019).

The final selection of catheter material will depend on the purpose of it. Overall there are 5 different application methods of catheters that will determine the choice in materials (Neurovascular, intravenous, urology, cardiovascular and specialty catheters)(Statista, 2019a). Within these different products a differentiation can be made based on the amount of time the catheters will have to be inserted. Based on estimates of Statista for the US catheter market, Cardiovascular catheters represent the largest revenue market. This is followed by speciality catheters market, Intravenous catheters, neurovascular catheters and finally urinary catheters (Statista, 2019a).

For the first application area of the catheters resulting from the VIPRISCAR project the research looks specifically at the cardiovascular catheters. This is market has been selected as it is the market where polyurethanes are the most used materials (VIPRISCAR, 2017), because of their good physicochemical and mechanical properties and good biocompatibility (V., H., Hernandez-Sanchez, & M., 2013). The key competitors in this field can be seen on the figure below Figure 20.

FIGURE 20: BENCHMARKING OF COMPETITORS ON DIFFERENT PARTS OF THE VALUE CHAIN

The majority of polyurethane catheters are based on aromatic isocyanates because of their lower biocompatibility than polyurethane based on aliphatic isocyanates (VIPRISCAR, 2017). These materials are however toxic, and they are prone to degradation. This toxicity is increasingly debated, and it is expected that there will be an incoming ban on the use of

isocyanate in polyurethanes to produce catheters (see PESTEL: P24). This change in legislation will bring the VIPRISCAR developed NIPUs into the picture and give them a head start in market uptake.
Furthermore, research has proven that polyurethane catheters present a higher risk for infections and thrombogenicity compared to silicone catheters. IBMC derived NIPU is planned to present also anti-thrombogenic features and can thus surpass the existing material on this aspect as well (Wildgruber et al., 2016).

3.2.3.2 Market size

The global catheter market had a total value of Us $ 26.60 billion in 2015, and it is estimated to grow at a CAGR of 9.7% by 2021, reaching a value of US $46.20 billion (Research, 2017). The initial market strategy will focus on polyurethane cardiovascular catheters.

Most of the European nations are leading exporters of catheter and other medical appliances. Together with the US and China, Germany and France are leading players (Trademap, 2019). This key position should be considered and exploited accordingly.

A more precise market sizing based on the target countries and targeted end users will be added in the exploitation plans that will be developed at a later stage of the project.

4. PORTER's 5 forces

Introduced by Michael Porter in 1980, the five forces model has been used consistently (Michaux, Cadiat, & Probert, 2015). Based on all the previous findings on competitors and competing technologies, the model allows a structured research and gives a coherent overview of the industry rivalry today and in the near future. Overall the figure will indicate how competitive the target market is, the strengths and weaknesses of the VIPRISCAR project and the potential competitive advantages.

To get to the complete overview, the model considers the following five forces: Power of suppliers, Power of buyers, Threat of substitution, Threat of new entry and industry rivalry. Each force will be considered in detail below and will be accorded a semi-quantitative score. Based on this score the overview in

Figure 21, is constructed.

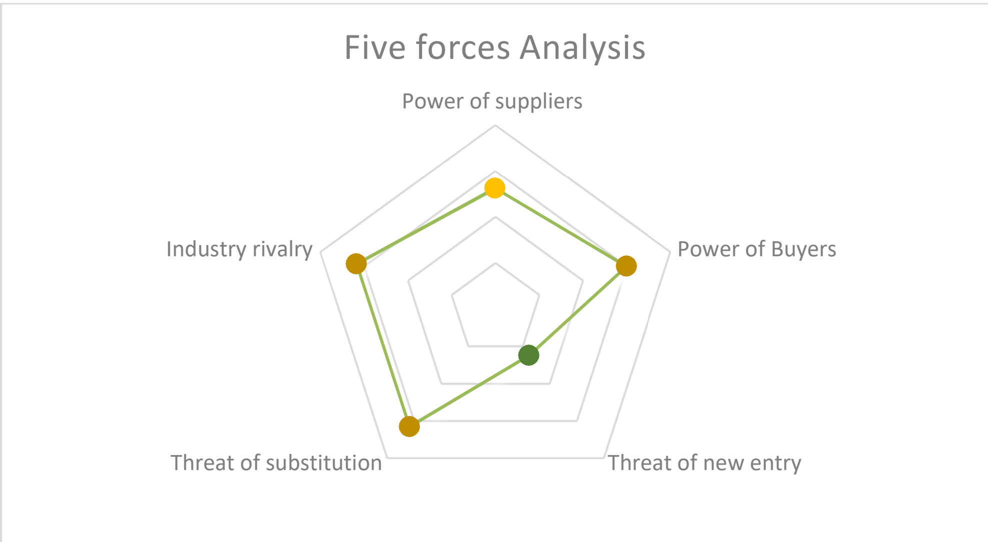


FIGURE 21: PORTER'S FIVE FORCES CONSOLIDATED ANALYSIS
SOURCE: VERTECH GROUP INTERNAL RESEARCH

4.1 Power of suppliers

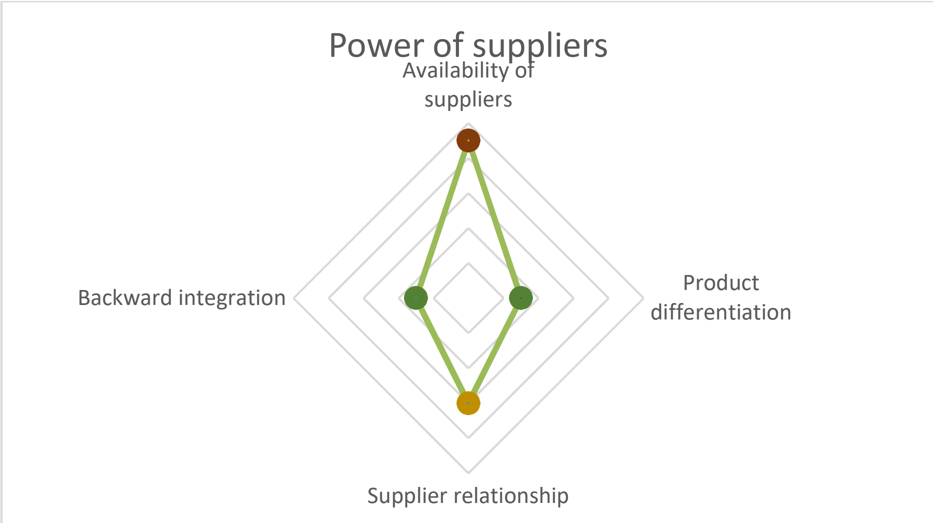


FIGURE 22: POWER OF SUPPLIERS ANALYSIS. SOURCE: VERTECH GROUP INTERNAL ANALYSIS

The first segment in the Five Forces analysis considers the power that suppliers can exercise on the producers of the IBMC. The more power the supplier(s) contain(s), the less freedom the IBMC producers, such as B4 plastics, will be able to exercise. It is determined by, amongst other things, how easy suppliers can increase prices, how niche the market they serve is and how niche their product range is. Overall it concludes how high the cost would be for a producer to switch supplier. The higher this cost the more power a supplier can and will exercise (Porter, 1980).

Isosorbide, the key raw material for the IBMC production process, is a primary bio-based chemical derived from corn-starch glucose. Over time this material can become widely available at a relatively low cost. Today however, the technology is not advanced enough yet. The market volume at the moment is currently too low to make the price competitive (31500t/y at €6.7/kg) (Grand View Research, 2016). At this cost there are very few suppliers providing this material. Although the isosorbide market is estimated to grow fast over the coming years (10.9% CAGR, (VIPRISCAR, 2017)), the limitation is currently providing a very high supplier power to those few suppliers such as roquette frères.

4.2 Power of buyers

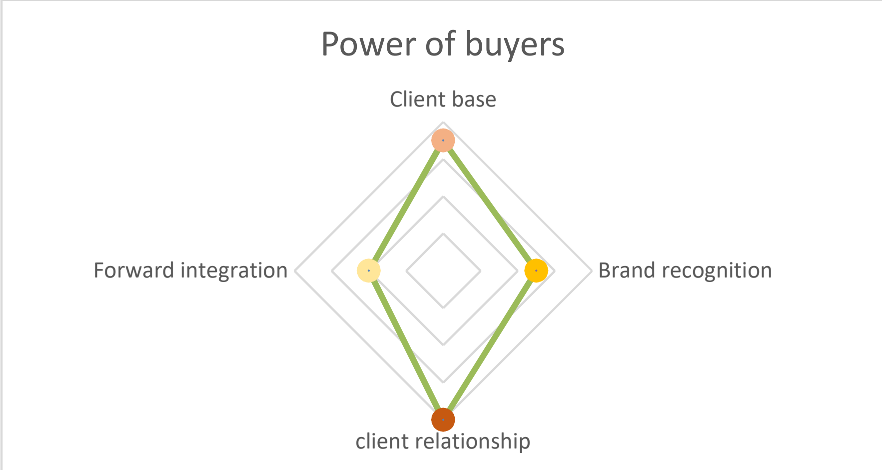


FIGURE 23: POWER OF BUYERS ANALYSIS
SOURCE: VERTECH GROUP INTERNAL ANALYSIS

The section of buyer's power answers the question of whether the buyers of the derivatives are so strong that they can dictate the terms and conditions of their purchase to the producers (Porter, 1980). This is determined by the size of the contracts or the number of clients one company has. In the different industries that are analysed here, the number of customers relatively large. As stated in the benchmarking analysis of each industry, the markets are dominated by 5 – 10 players. These players have gained significant market share through mergers and acquisitions. Attaining one of these key players as a client is a great achievement and a contract with these firms will be negotiated mainly according to the terms set by the buyer.

Furthermore, the power of the brand name and reputation is relatively low for producers of chemical derivatives. This is because the end customer has generally little knowledge about the intermediary products inside the catheters, coatings or adhesives. Although these intermediate products represent a significant part of the final cost, and can impact the characteristics of the material, the derivatives are very specific and require industry knowledge beyond the initial understanding. The low brand recognition enables the buyer to switch supplier in case certain contract terms are not meeting their expectations.

Nevertheless, the property requirements of the materials that a certain buyer demands can be specific and might require additional research and adaptation from the producer's side. This makes it important for both parties to have a positive, long–term relationship, build on trust and cooperation. This gives the producer leverage to implement their terms and slightly reduces the power of the buyer overall.

Finally, buyer power should consider the risk, or opportunity, of a forward integration of the producer by the buyer. This would be a mean for the coating or adhesives producers to increase their profit margin and establish their market share on different parts of the value chain, in the industries analysed for the purpose of VIPRISCAR.

4.3 Threat of substitution

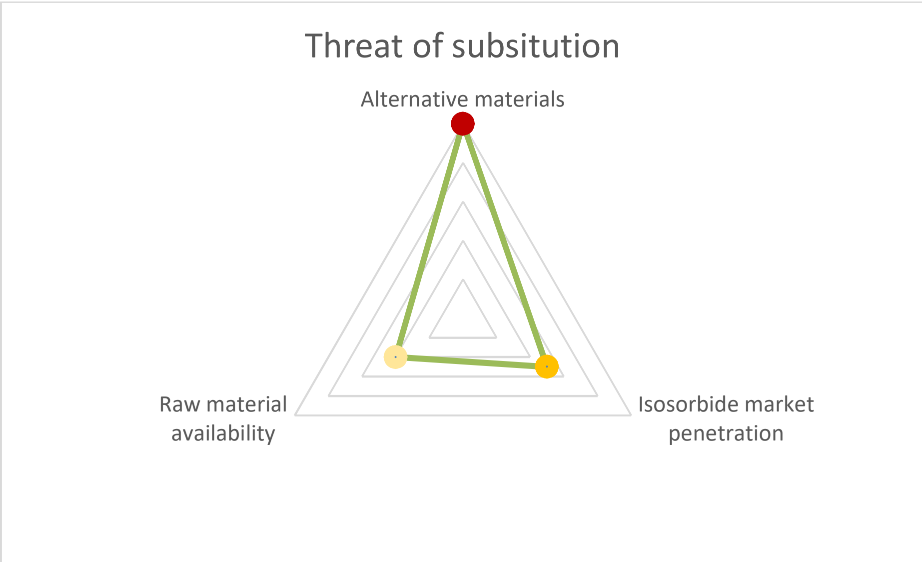


FIGURE 24: THREAT OF SUBSTITUTION ANALYSIS
SOURCE: VERTECH GROUP INTERNAL ANALYSIS

The threat of substitution looks at the alternatives that exist for the IBMC material. The quality and the quantity of the substitutes available, compared to the originally research product, will determine the importance of this threat. Polycarbonates are no new material when it comes to any of the industries analysed. There are current existing methods that allow to produce coatings or adhesives from polycarbonate materials. The same is true for polyurethane based end products. The vast majority of these however, contain Isocyanate. The particularity of the VIPRISCAR research is the development of non-isocyanate polyurethanes. Because of the growing market that exists for this, there is research conducted on NIPUs and some early stage versions might exist. The IBMC, developed first by Tecnalia and scaled by VIPRISCAR will however be the first polyurethane that is both isocyanate free and bio based with antimicrobial and antithrombogenic characteristics.

Market penetration can on occasion be facilitated if there is an existing, similar product on the market. This is because first mover advantage, depending on the industries, are not necessarily advantageous (Suarez & Lanzolla, 2005). Therefore, it is positive that the substitutes are there, constantly increasing the market size for coatings, adhesives and catheters. Nevertheless the status quo is often difficult to break and the existing materials and substitutes therefore represent one of the largest risks to the introduction of VIPRISCAR.

4.4 Threat of new entry

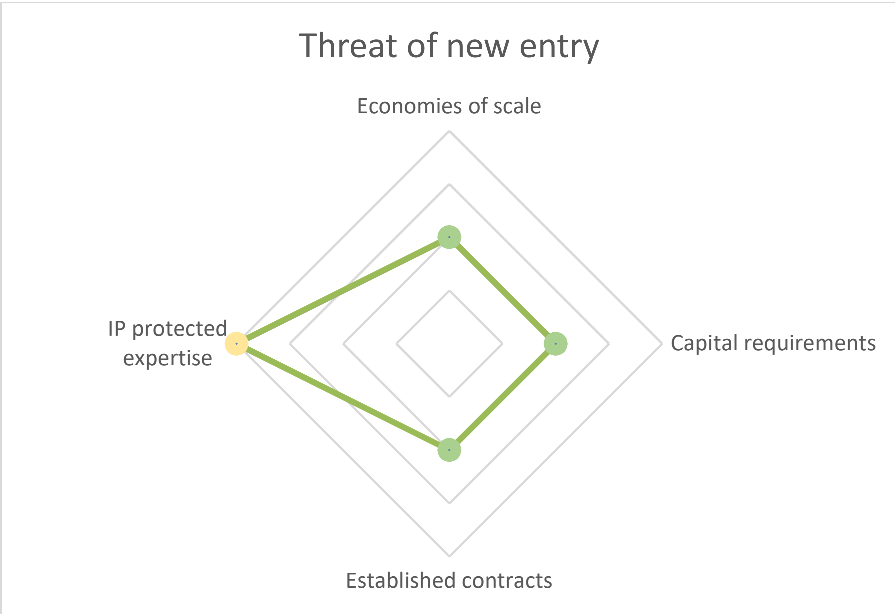


FIGURE 25: THREAT OF NEW ENTRY ANALYSIS
SOURCE: VERTECH GROUP INTERNAL ANALYSIS

The fourth segment considers the constant changes of a market and guides the market strategy considering how easily the IBMC producer's position can alter when new players come into the market. To assess this risk the research considered the cost that will be attached for a new company to come in and take away market share from an existing player (Porter, 1980).

Within the chemical derivative production industries, economies of scale are significant. For the production of IBMC they are present under the form of high fixed cost for R&D or equipment set up, similar to the cost of all derivatives production plants. A company can only start being profitable once it has covered all these costs with sufficient revenue from the operations. The relatively high economy of scale in this industry is positive, as it increases the barriers to entry of potential players that might not be able to overcome this initial cost.

Moreover, the high consolidated market that is operating in each of the 3 sectors and that leverages high market share makes it even more complicated for entrants to come in an establish their name amongst the large players. Even beyond the leading 5 firms, the additional players that try to obtain between 0.01% and 3% of the market face high set up cost and set the market entry barrier higher. This comes from strategies such as locking in the buyer and making them dependant on the product through long term contracts, or by adapting their product diversification list so wide it requires a lot of time and money to be able to provide all this expertise.

4.5 Industry rivalry

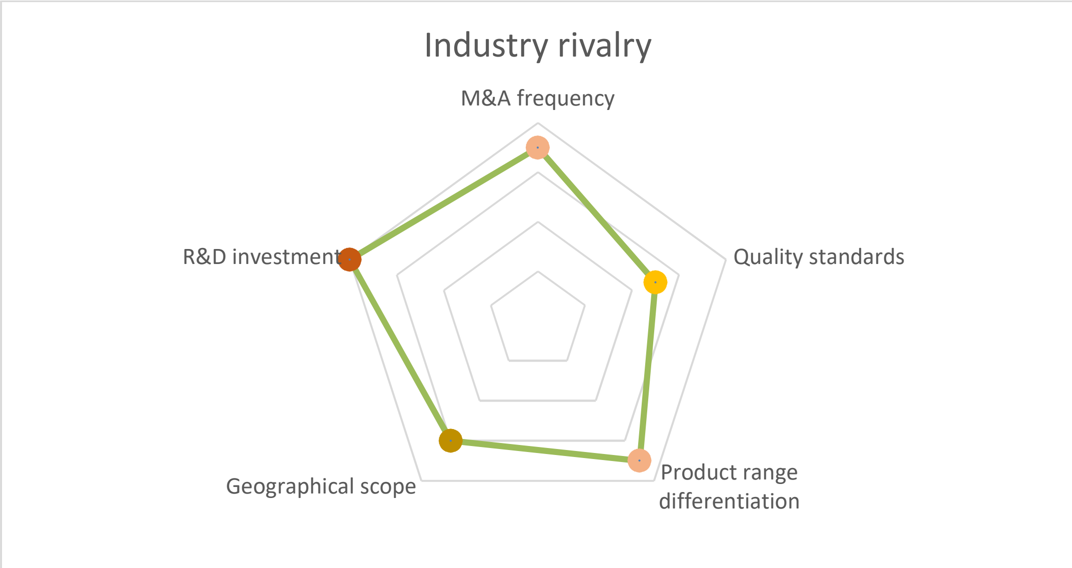


FIGURE 26: INDUSTRY RIVALRY ANALYSIS
SOURCE: VERTECH GROUP INTERNAL ANALYSIS

The industry rivalry will indirectly influence all factors discussed above. But the section looks in detail at the number of competitors, their strengths and weaknesses and what their presence means for the producing company.

It was highlighted in the paragraph above again that the number of competitors in this market are limited. There are a few key players that will dominate most of the market and followed by hundreds of small competitors that each battle for a small market share before being take over by one of the leading players. The increasing pressure from Asian partners increase the rivalry in Europe and other parts of the world.

The merger and acquisition strategy is common in the industries as an approach to growth. This is for many reasons, including the long-term relationship and client lock in that is used as a buyer retainment strategy. For competitors to acquire a certain client, acquiring the supplier might be the only way.

As an intermediary product, the quality of the product is important but will leave room for very little variation. Although there might not be an immediate standard for the derivative produced but it is important for the end product. Particularly for catheters there are tight requirements (VIPRISCAR, 2017).

These standards and closely linked products shift the competition of the industry towards a price and product range focus, leading to differentiation on geographical scope and the potential to invest further in R&D.

5. CONCLUSIONS

The complete market analysis proves that the production of IBMC, enabled through the synthetisation of isosorbide mono(methyl carbonate) represents large potential in the catheter, industrial coating or hot melt adhesives market. The scaling of this material brings to light a solution to the existing problems that are present in the state-of-the-art products. IBMC polycarbonates and polyurethanes operate indirectly in markets that all together amount to a total of more than US$ 100 billion (Industrial coating: US$ 74,913 million (Mordor Intelligence, 2018), Hot melt adhesives: Us$ 6,480 million (Technavio, 2018) and catheters: US$ 26,600 (Research, 2017) in 2016, 2016 and 2015 respectively). .

The PESTEL analysis points out certain factors that indicate a decrease in overall growth of the coatings, adhesives or catheters market. Although this will affect the total potential in the long run, IBMC derived polycarbonates will replace the existing materials for coatings and hot melt adhesives. The market uptake in this sector can therefore develop relatively fast, once the product is ready for scaling. Highlighting the competitive advantages in this market analysis and in further exploitation plans will show the benefit from adopting IBMC based polycarbonates in the near future.

The IBMC derived non-isocyanate polyurethane (NIPU) on the other hand is facing a young market. The general market in which it operates is highly saturated but currently no close direct competitors exist. The market strategy for the commercialization of this product will require careful planning and organisation prior to launching.

These strategies will be developed throughout the exploitation plan that will be updated on a regular basis throughout the project lifetime.

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7. Annex:

7.1 Annex 1: PESTEL Analysis semiquantiative consolidation of analysis

Risk analysis		
Political factor	**Impact**	**Likelihood**
BREXIT	-7	9
tax reduction	5	5
Economical factors		
GDP Growth	2	2
Social factors		
Internet purchasing	4	6
Aging population	5	6
Urbanization	4	5
Quality of life & economic development	4	7
Individualization of society	6	3
Environmental awareness	7	9
Technical factors		
Welding to adhesives	6	5
Environmental pressure	6	6
Environmental factors		
VOC requirements	9	7
Asian market slowdown	-2	4
Bio-based coating	7	5
Legal factors		
REACH	4	7
FEICA	2	3
Banned products	8	4
Single use plastic	-1	3
No Global consensus	-2	4
International standards	4	4

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