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An economic analysis of plastic recycling process

TECHNICAL, CHEMICAL AND ECONOMICAL ASPECTS OF PLASTIC RECYCLING PROCESS

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Abstract

The present study analyzes the historical and current trends of plastic recycling industry of Europe followed by the economic analysis of plastic recycling firm ‘Quantafuel’. The study uses two different approaches i.e., financial analysis and Porter’s five industrial analysis to analyze the company’s performance and overall trends in Europe. The financial (economic – cost/benefit) analysis has been performed using fourteen different ratios i.e., equity ratio, earnings per share (EPS), debt-to-equity ratio, return on equity (ROE), working capital ratio, return on invested capital (ROIC), return on assets (ROA), gross margin, operating margin, net margin, economic value, capital employed, cost of capital and WACC for the time period 2018-2021. As the company was founded in 2017, thus the results shows that company is not generating profit but is on its way to recovery and soon will be genertaing enough profit. The decline in negative statistics over the specified time period showed that Quantafuel is making progress day by day as it is also expanding it's business in Europe. Secondly, the porter’s five analysis showed that the five porter’s forces significanlty affects the European plastic industry and the performance of the Quantafuel.

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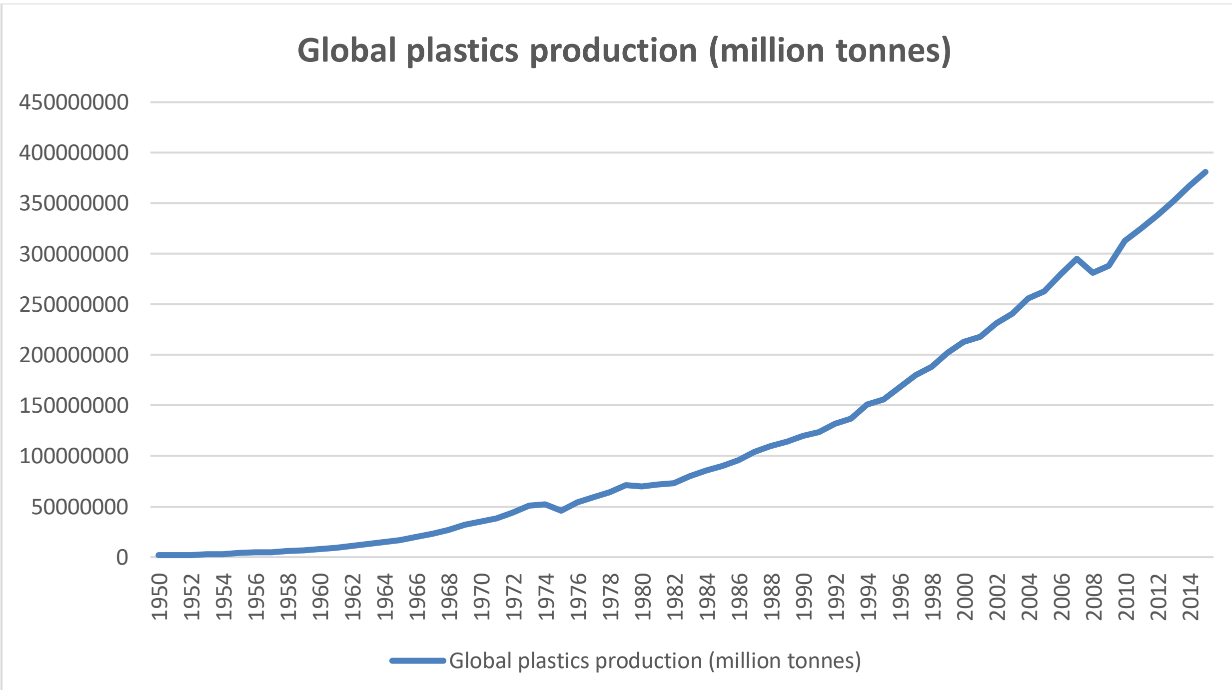
1. Introduction:

1.1. Importance and uses of plastic:

In today's evolving world of humankind, the importance of plastic and its usage has been increased significantly with the passage of time. Plastic as a polymeric material is being used in multiple forms in everyday life and in the production of goods in almost every economic sector. The evolution of plastic materials verifies a change in the habits of the population (De Sousa, 2021). Humans have benefited from plastic since 1600 BC (Andrady & Neal, 2009). Some of the main sectors and areas in which plastic is mainly used are aerospace, construction, electrical and electronic applications, packaging, automotive industry, energy generation, furniture, marine, medical and healthcare, military and other consumer products. The greater use of plastic nowadays is in the packaging of consumer products. It highly contributes to sustainable development. The lightweight plastic packaging saves energy while transporting the goods in terms of less consumption of fuel and lower emissions, which saves the cost for retailers, consumers and distributors. It uses optimal resources, can prevent food waste and is re-useable (BBF, 2022). Packaging usually comes under food supply; single-use plastic items in everyday life (Sattlegger et al., 2020).

The high usage of plastic is leading to high plastic production because it tends to be an inexpensive, strong, durable, and lightweight material. It has been increased around the world in almost every region; Europe, the United States, China and many more (Thompson et al, 2009). Increased production, consumption and waste disposal tends to damage land and environment. Plastic pollution does not only lead to environmental or health damage, but it also deteriorates the economic conditions of the countries. For example, the inverse relationship between environmental degradation and per capita income is known as environmental Kuznets curve. It states that with the rise in environmental degradation, the per capital income declines and this rise in environmental degradation is mostly because of plastic pollution. Data shows that global plastic resin and fiber production grew from 2 million metric tons (Mt) in 1950 to 380 million (Mt) in 2015 (Barnes, 2019).

Figure 1: Global Plastic Production



Source: Our World in Data (2022)

The above graph shows the annual global plastic production in million tonnes from 1950 to 2015. The world production of plastic was 2 million tonnes per year and then it increased significantly reaching around 380 million tonnes produced in 2015. This increasing production shows the increasing demand of plastic.

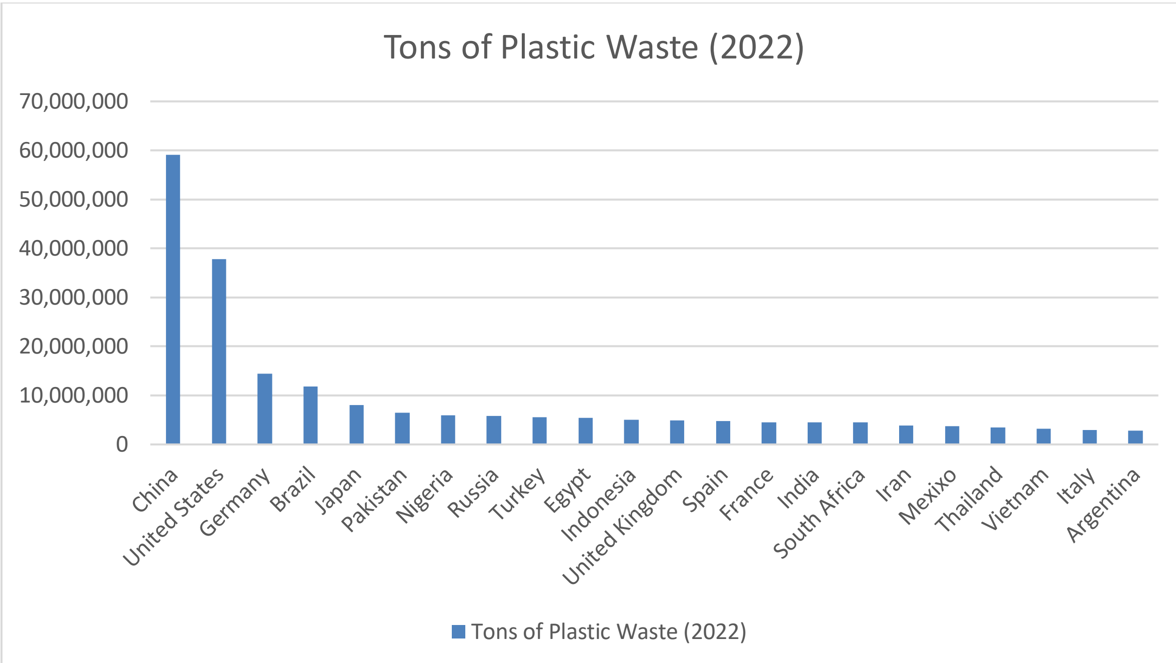
1.2. Plastic, sustainable development & externalities:

Plastic packaging extends the shelf life of commodities and products held in warehouses and on supermarket shelves, making it a practical embodiment of the sustainability principle. Up to 50% of food resources are wasted in underdeveloped nations because, among other things, modern packaging materials such as plastics are not commonly employed for packaging, safeguarding, and prolonging the shelf life of food goods. These losses are minimised to as little as 3% in most developed countries, where far more plastic packing is utilised. In addition, the use of plastic packaging generates considerable fuel savings when transporting goods, as lightweight plastic packaging constitutes only 3.5% of total product weight, whereas packaging made of other materials can weigh even ten times more. Moreover, in the last 10 years, the average weight of plastic packaging has dropped by around 28% (Plastics Europe, 2019).

Despite having numerous benefits of plastic, the usage and approaches to production methods seem to be inefficient and unsustainable for humans and wildlife. It creates environmental hazards which further deteriorate human health in multiple ways (Thompson et al, 2009). The durability of plastic is deeply concerned with society's changing habits. The consumption of plastic leads to the disposal of post-used plastic, which creates waste accumulation and aggravates socio-environmental problems (De Sousa, 2021).

The high use of plastic in everyday life increases the probability of a high quantity of plastic waste. It depends on the societies who are providing food and in what way. Hence, waste from plastic packaging is one of the main socio-ecological problems society and nature can face. There is a need to overcome this issue by adopting concerning practices (Sattlegger et al., 2020). This plastic pollution has now become a major source of concern for government officials, stakeholders and investors. This issue has emerged to the extent where it has started affecting negatively ocean and terrestrial ecosystems.

Figure 2: Tons of Plastic Waste



Source: World Population Review, (2022)

The above graph shows the top twenty-two countries that generated plastic waste. From these countries, China is number one. However, the European countries i.e. Italy seem not to generate much plastic waste as compared to China and the United States.

However, the statistics show that around 25.8 million tonnes of plastic waste is generated every year in Europe and around 150000 – 500000 tonnes of plastic waste enters the oceans every year (Europarc, 2018).

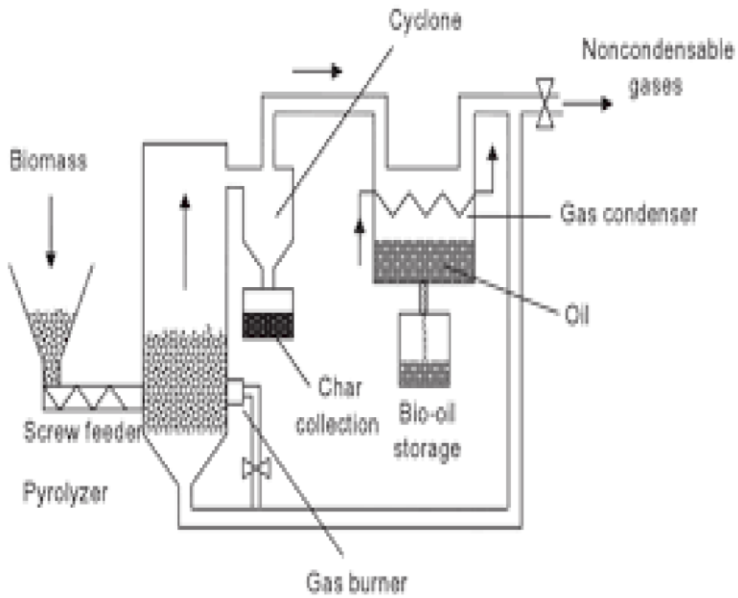
1.3. Chemical Aspects of Plastic Recycling

As it is the chemistry that leads to the manufacturing of plastics, hence it is reasonable to acknowledge its chemistry to find possible paths of recycling plastics in order to produce monomers or reusable smaller products. With respect to chemistry, plastic waste in the recycle streams can be divided into thermosetting and thermoplastic types. Although the majority of thermosetting plastics that are cross-connected can be decomposed only through pyrolysis for the production of fuels or hydrocarbon feedstocks, or are incinerated to recover energy, polymers comprised of thermoplastic solids are either step-growth condensation polymers like polyesters, polyurethanes or polyamides that are manufactured by condensation or addition polymers in case of which the synthesis reactions are not reversible essentially (Sasse & Emig, 1998) . Hence, while polyamides or polyesters can be recycled and depolymerized into plastics, depolymerization of other polymers demands pyrolysis or intense chemical reaction which usually forms a broad spectrum of species of varied sizes, providing less in the path to get desirable products in economically feasible yields.

It needs to be acknowledged that although recycling strategies are required particularly by the differences in chemical reactivities and different plastics have their specific characteristics, there exist many other practical features from collection to sorting to pretreatment which impact the selection of recycling method to be used. Hence effective recycling of plastic should be sorted according to its type (Hornberger, 2003). Nonetheless, the plastics recycling practice, directed by economic, legislative, and consumer pressures is all but definite to expand, the basic factors in the growth rate are the ability of the plastic industry to create an economical material collection framework and to boost the practices for handling as well as the processing of contaminated scrap in order to identify and classify them effectively and quickly (Kaminsky, 2000).

There exist various chemical or tertiary methods for recycling plastics. For instance, chemical methods like glycolysis, hydrolysis, and methanolysis are effective in unzipping the condensation polymers like nylons, polyurethanes, and polyesters. Promising yet inconvenient novel methods like supercritical fluid mediation, microwave irradiation, ionic fluid treatment, tandem catalysis, and enzymatic decomposition are also used for recycling polymers (Kaminsky, 2000). Pyrolysis is a significant chemical method used for recycling and has a high potential for heterogeneous plastic waste that is difficult to be separated economically. This process is considered because it significantly converts plastics into oil and generates gaseous products of high calorific value which can be utilized to meet the fuel needs during the process. Nonetheless, the embodied energy available for recovery by combustion is comparatively less than the amount utilized in pyrolysis and plastic manufacturing. Furthermore, depolymerization through pyrolysis at temperatures greater than 400C in the absence or presence of the catalyst forms a very complex and almost inseparable mixture of hydrocarbons, char, and gas, that's a big drawback (Simon & Kaminsky, 1998).

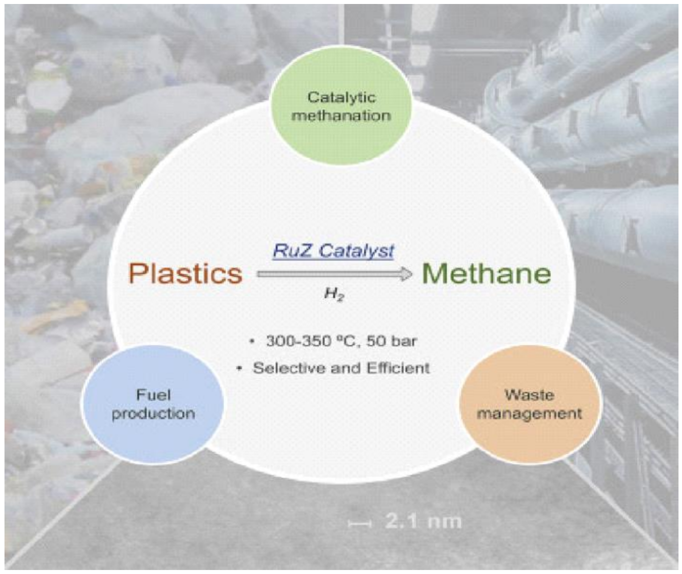
Figure 3: Pyrolysis of Plastic Waste



Source: Pandey (2020)

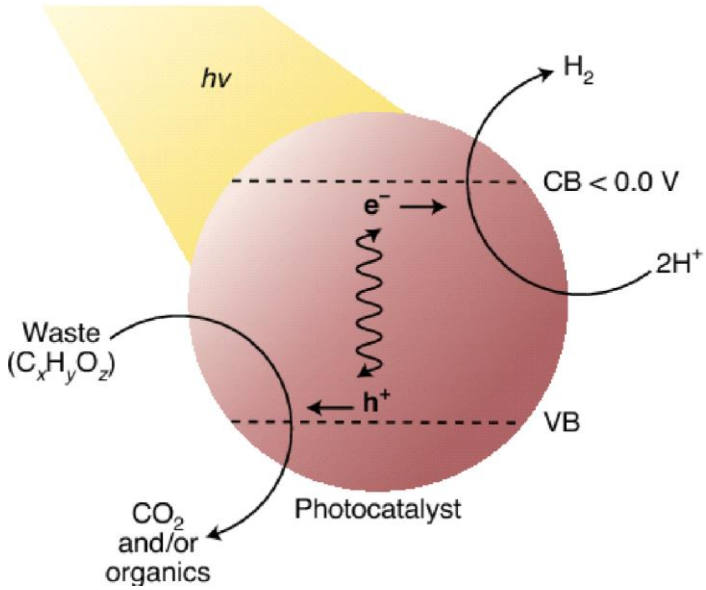
In the case of catalytic hydrocracking, although they provide more selective degradation at a lower temperature, the economies of the method are not that suitable. Compared to these methods, the novel solar-driven plastics reforming is a significant approach. For the demonstration of these methods, effective photoreforming of three major polymers -PET, PU, and polylactic acid is carried out utilizing inexpensive CdOx or CdS quantum dots in an aqueous alkaline solution. The visible-light-driven and metal-free photo reforming method generate pure hydrogen at ambient pressure and temperature, and the waste polymer is transformed into suitable organic products like acetate, pyruvate, and formate (Simon & Kaminsky, 1998).

Figure 4: Catalytic hydrocracking of plastic



Source: Lee (2020)

Figure 5: Solar driven reforming of plastic waste

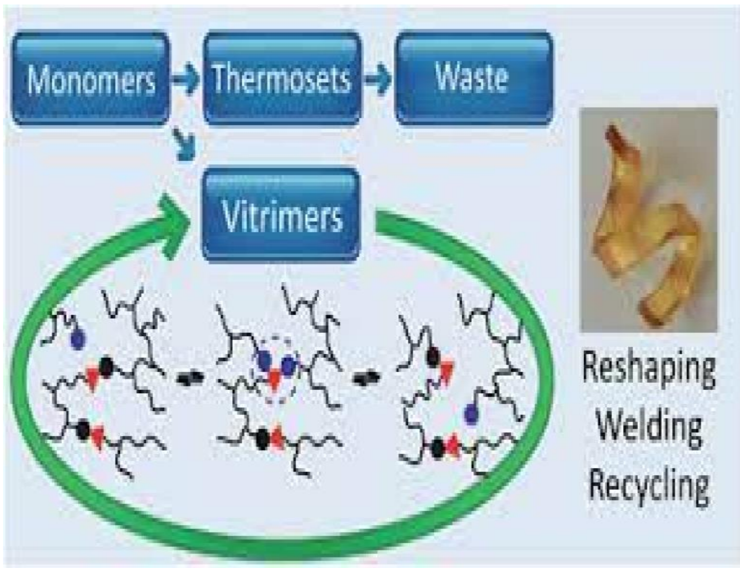


Source: Uekert (2020)

Realizing the fact that the issue of plastic waste, its disposal, as well as recycling, is an inescapable outcome of the nature of the chemical composition of plastics which have been manufactured in the lab, the effort to generate new polymers is increasing will ease the circular economy and closed-loop recycling, likewise what applies to PET currently (Chanda, 2021). It is found that the closed-loop polymers are important to sustainability practices globally and their incorporation into the global products ecosystem is based on the maintenance of high value for recycled components at the end of the products life, as also on lessening the energy intensity and cost of depolymerizing polymers, for which, even reducing the energy barrier to bond cleavage is crucial (Kaminsky, (2000).

The potential solutions to such issues have evolved from recent advancements in dynamic and catalysis covalent chemistry. Specifically crucial is the emergence of dynamic covalent copolymers called 'vitrimers', considered sustainable alternatives for non-recyclable thermoset plastics. Whilst vitrimers undergo relational bond exchange reactions in the solid-state, it enables cross-linked products to be processed and recycled thermally like thermoplastics while sustaining high cross-link density. Vitrimer-based recycling approach, however, highlights a turn back to original monomers and reemergence to the supply chain, hence largely restraining reformulation opportunities (Chanda, (2021). Comparatively, new plastics constituting dynamic covalent diketoenamine bonds enable monomer's recovery from common additives even in blended plastic streams. Hence polydiketoenamine portrays a high possibility for closed-loop recycling, seems to click together from a broad range of aromatic amines and triketones, with by-product water, while also having the potential of hydrolyzing in vigorous aqueous acid at surrounding temperature to produce reusable and pure triketones (Hornberger, 2003).

Figure 6: Structure of Vitrimers



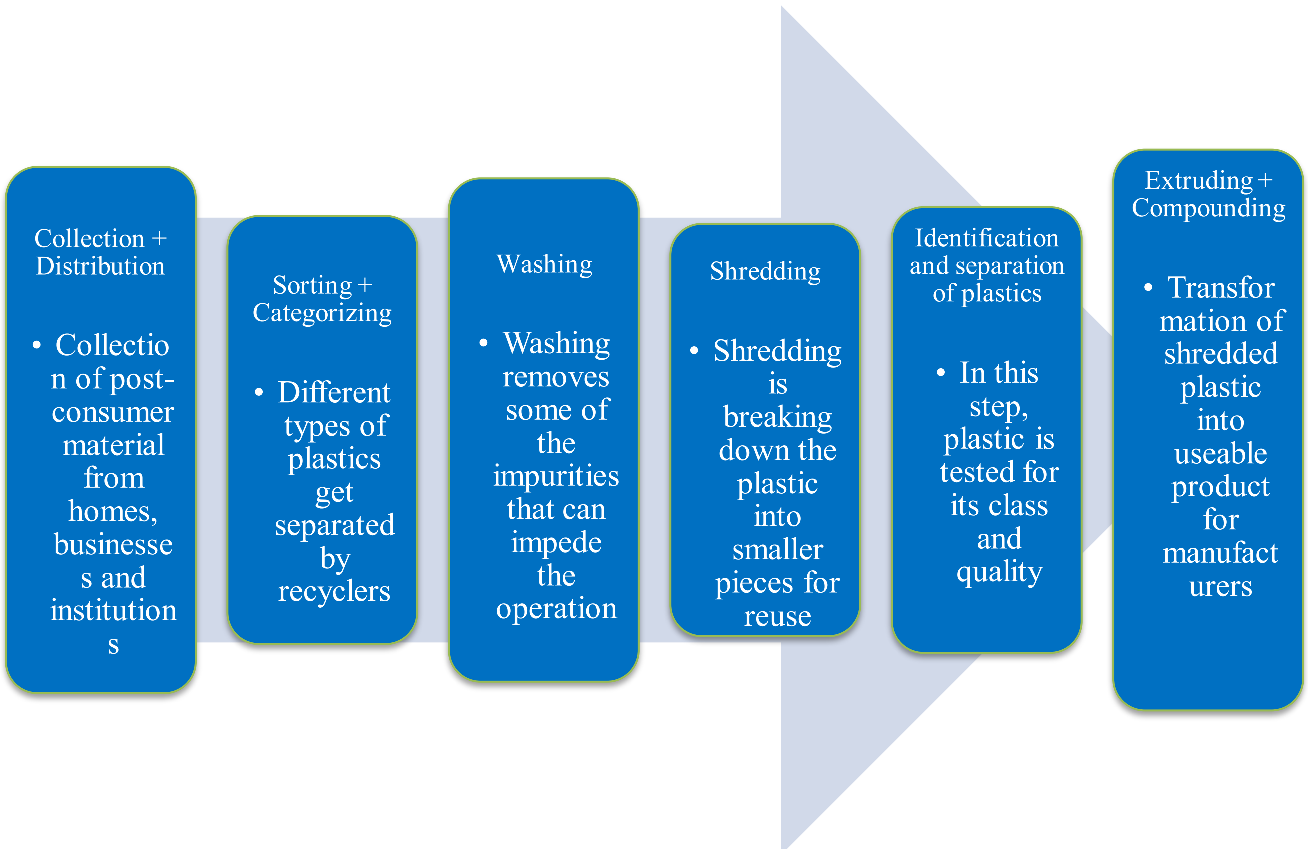
Source: Denissen et al., (2015)

Nonetheless, it needs to be affirmed that although the circular use of plastics aid in preserving finite natural resources apart from dealing with end-of-life consequences, to substitute contemporary commercial polymers or plastics, depolymerizable polymers being made should match the characteristics of current polymers commonly used.

1.4. General process of plastic recycling:

Plastic recycling is simple yet complicated process because of differnet steps. It is critical as a means of dealing with current garbage and as part of circular economy and zero-waste systems that aim to reduce waste output and promote sustainability.

Figure 7: General process of plastic recycling



Source: RTS (2020)

Plastics abound in the earth. Whether you realize it or not, almost everything you see and use every day is made totally or mostly of plastic. Plastic materials are used in your television, computer, automobile, house, refrigerator, and many more critical things to make your life easier and more uncomplicated. However, not all plastics are created equal. Manufacturers use a range of plastic materials and compounds, each with its own set of qualities. Hence, the different types of plastic are shown in the figure below:

Figure 8: Types of plastic

1. PET	2. HDPE	3. PVC	4. LDPE	5. PP	6. PS	7. OTHERS
Polyethylene terephthalate	High-density polyethylene	Polyvinyl Chloride	Low-density polyethylene	Polypropylene	Polystyrene	Other
Examples: Water Bottles, Jars, Caps	**Examples:** Shampoo Bottles, Grocery Bags	**Examples:** Cleaning Products	**Examples:** Bread Bags, Plastic films	**Examples:** Yogurt cups, Straws, Hangers	**Examples:** Take-away and packaging, toys	**Examples:** Baby bottles, Nylon, CDs

Source: RTS (2020)

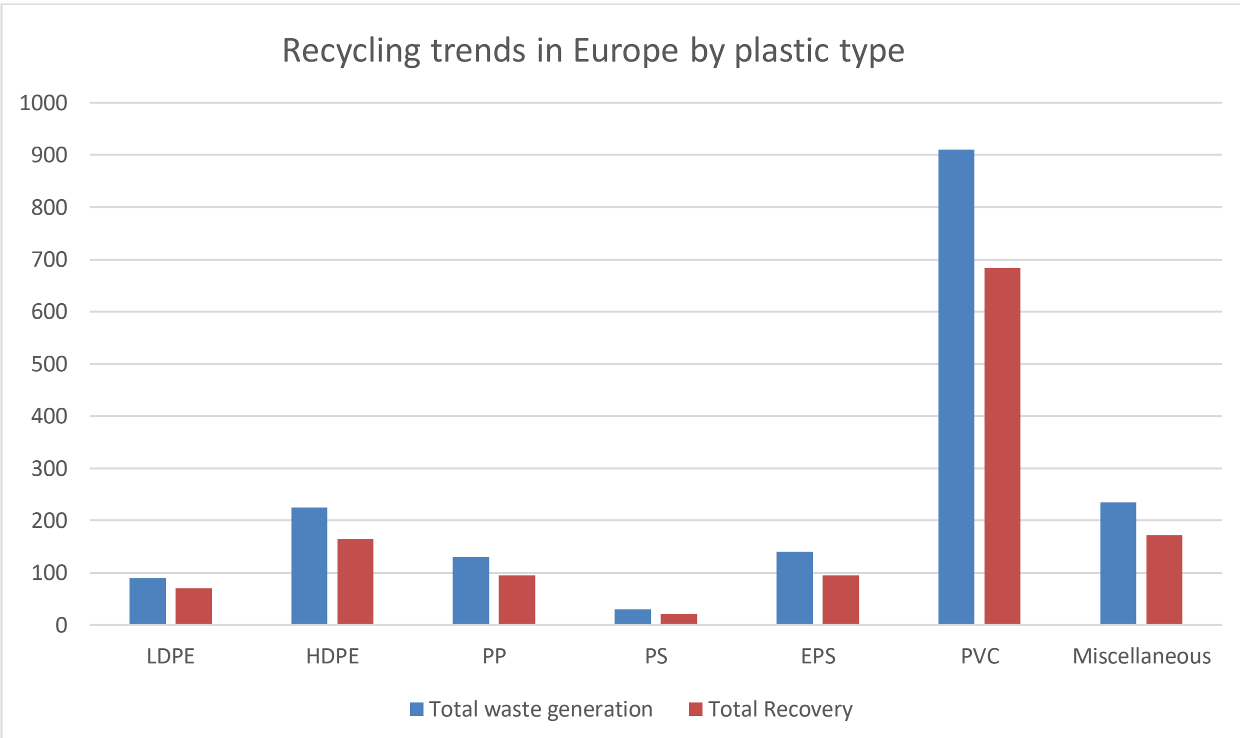
Plastic recycling is a process in which the amount of waste that ends up in the oceans is reduced by recycling plastic. New jobs are created as a result of plastic recycling. For the government and commercial entities, plastic recycling generates additional cash. Recycling plastic decreases the amount of carbon dioxide and other hazardous gases released into the atmosphere. It reduces the amount of area taken up by landfills. It allows those landfills to be used for other purposes. Recycling conserves petroleum, which can be used to create new plastics. Plastic recycling reduces the amount of energy used by manufacturers to create new products. Global warming is avoided by recycling plastic. Plastic recycling helps to reduce pollution in all kinds. Volunteers that collect plastic debris earn money by recycling it. Plastic recycling aids in the reduction of activities such as deforestation that occur during the manufacture of new plastic.

Even though many of the elements related with recycling are social or environmental in nature, the focus is usually on the more concrete, economic sides of the process. (**Recycling: theory and reality).**

1.5. Recycling trends in Europe:

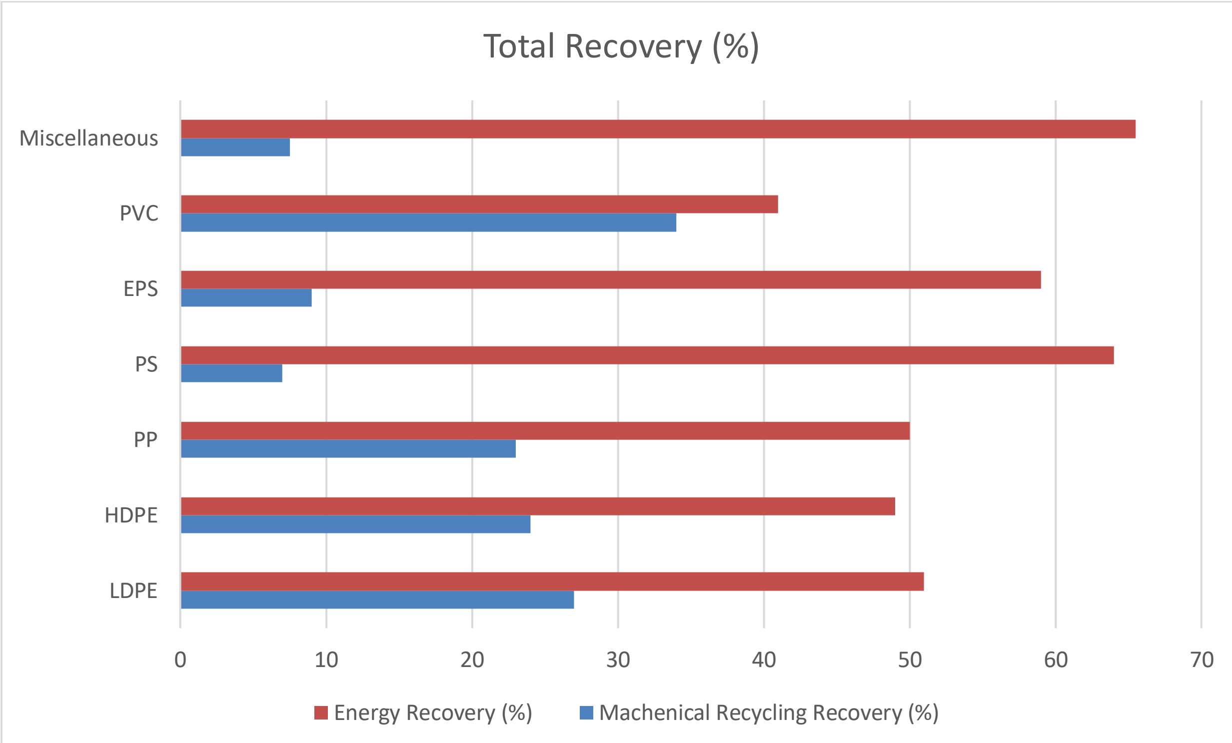
In Europe, 8.4 million tonnes (27.9%) of the 30 million tonnes of plastic collected in 2016 were recycled, whereas 3.1 million tonnes (10.3%) were sold outside Europe, 11.3 million tonnes (37.3%) were utilised for energy recovery, and 7.4 million tonnes (24.5%) were dumped. The table below shows the waste generation and recovery with respect to types of plastic.

Figure 9: Recycling trends in Europe by plastic type



Source: ***EuRIC: Plastic Recycling Factsheet***

Figure 10: Total Recovery (%)

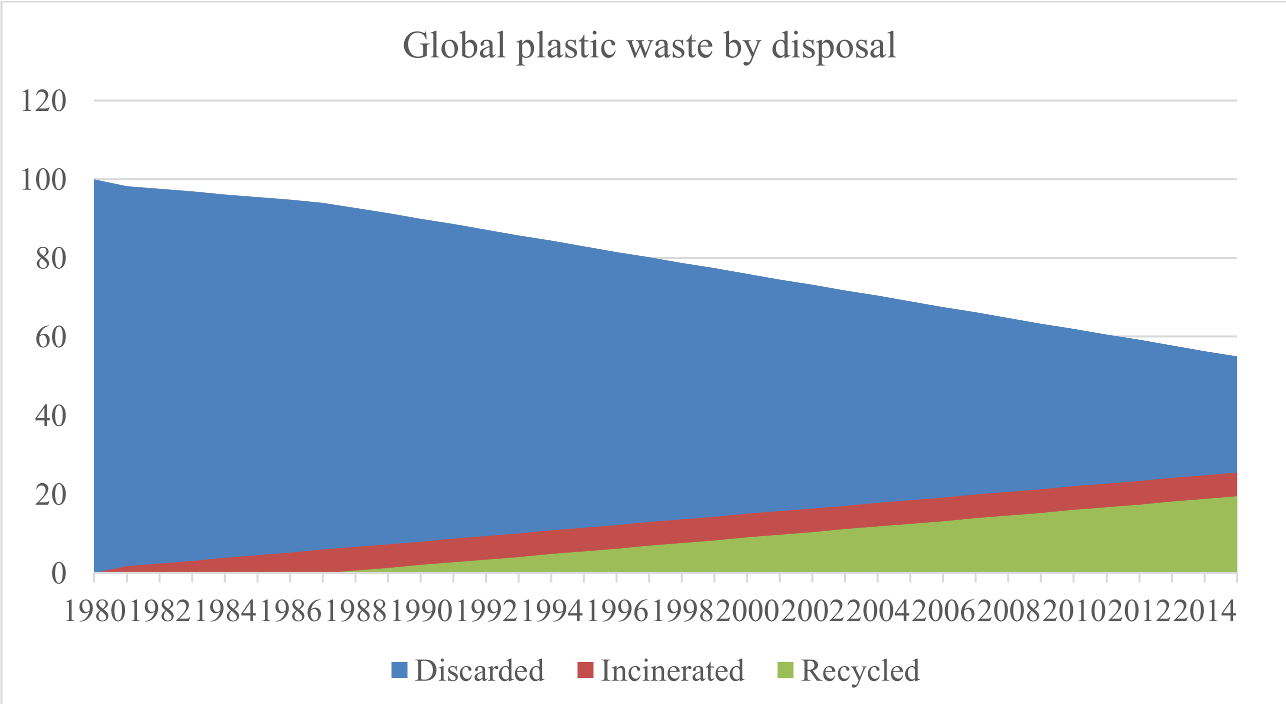


Source: Euric: Plastic Recycling Factsheet

1.6. National and international strategies for plastic pollution:

The sensitivity coming from the harmful effect of human activities on the environment led to the UN 2030 agenda for sustainable development. In this agenda, the organization proclaimed its determination to protect the planet through sustainable production, consumption and recycling levels (Scuderi, 2021). Further, according to the European strategy for plastics in a circular economy (2018), despite being an important element in daily life, plastics are harmful to the environment and human health. This EU strategy builds on existing measures to reduce plastic waste and increase plastic recycling by achieving specific targets by 2025 (Europarc, 2018).

Figure 11: Global plastic waste by disposal



Source: Our World in data (2022)

The above figure shows the data of global plastic waste by disposal. It shows that a high percentage of plastic waste is being discarded which a very small percentage is being recycled from 1980 to 2014. But in recent years, the level of recycling has been increased to achieve sustainable goals.

At the national level, Italy introduced a tax on the consumption of plastic items (single-use) – MACST. This tax by the Italian government aims to reduce plastic consumption and therefore the generation of waste. The net revenue from this tax was estimated to be a significant amount under Euro 470 million for 2021 and Euro 290 million for the year 2022. However, the implementation of the "Italian plastic tax" has been postponed to 2023 due to the COVID-19 crisis (Scuderi, 2021).

The COVID-19 pandemic has a noticeable role in the high usage of plastic at the national or international level. The pandemic increased the medical waste (mostly made of plastic) while increasing the use and demand of single-use plastic items. The single-use items have been necessary since the start of the pandemic to maintain cleanliness, hygiene and other safety measures. With the noticeable rise in medical waste, the pandemic declined the recycling of dangerous chemical substances. The use of disinfectants increased the ecological risk to the ecosystem (Patrício Silva, et al., 2021).

Hence, there is a dire need to achieve a sustainable level of plastic recycling given the enormous effects of plastic pollution. Studies show that to achieve the sustainable target of recycling, policymakers may need to rethink the designs of plastic products, which must make them fully recyclable. At the same time, there are multiple challenges to achieving a sustainable level of recycling. For example, recycling targets cannot be achieved only by a single industry in Italy. The process of recycling should be taken care of by the combined effort of municipal and regional administration to achieve the goals with proper economic analysis (Paletta et al., 2019). One of the biggest challenges in the process of recycling is cost-effective analysis. Not every recycling method is cost-effective. The program or method should include low cost and efficient output (Shagiakhmetova, 2020).

1.7. Problem statement:

Platic is one of the most used products around the world. With the increasing plastic usage, the quantity of waste is also increasing which is further casuing harm to enviornment and society. Therefore, the recycling of plastic is essential to tackle the externalities genrated by plastic. However, there are differnet types of costs associated with the recycling procuders. Therefore, it is important to balance the costs with the benefits incured by the waste managemnt companies. Thus, this study will analyze the cost-benefit analsyis of a European plastic recycling ocmpany.

1.8. Objectives of the study:

The objectives of this study are following:

- To explore and analyze the plastic recycling trends in Europe
- To explore and analyze the plastic recycling trends in Italy
- To conduct a cost-benefit analysis of plastic recycling European company

2. Literature Review

This section analyzes the existing research on cost-benefit analysis of plastic recycling in Europe and around the globe. The section also analyzes the challenges the plastic recyclers face.

2.1. Economic Analysis of plastic waste recycling – European perspective

Plastic pollution has increased significantly over time. Therefore, recycling is a process to encounter the plastic waste generated. Hence, there are multiple factors that are considered extremely important i.e. economic analysis or the economics of recycling. According to the analysis of Bogert & Morris (1993), the cost of recycling is much lower than the cost of disposal in four geographically diverse Wahington state cities; Seattle, Spokane, Bellingham and Vancouver. In this study, costs and prices are compared for five recycled materials. Results revealed that recycling can be less expensive than disposal, according to cost statistics from four Washington communities from 1992, especially when factoring in the cash that can be obtained from selling recovered items. Findings also depict the net costs of the recycling and disposal systems (total expenses less any earnings from the sale of recycled materials or power generated by incineration).

Gradus et al., (2017) conducted a cost-effective analysis for recycling and incineration considering the Netherlands household's plastic waste. They compared the two different methods i.e. recycling and incineration by estimating their costs and revenues. First, the cost-effective analysis showed that the cost of CO_2 reduction by recycling method is much more expensive than the costs compared to market-based and external costs of carbon dioxide prices and the prices of other technologies like wind and solar etc. Statistics obtained from the analysis revealed that the price of declining under recycling method is 1 ton of CO_2 is €178, which is significantly greater than external and current prices. These higher costs of plastic recycling have multiple reasons i.e. first, higher prices of waste collection method, higher costs of treatment and process of recycling. Second, the amount of reduction of CO_2 is far less in the recycling method. Further, sensitivity analysis showed that the reduction in the costs of collection methods can decline the recycling costs.

The cost-benefit analysis of packaging waste management conducted by Ferreira et al., (2016) shows the costs and benefits of packaging (plastic) by local authorities in three European countries Portugal, Belgium, and Italy (Lombardia). The expenditures (costs) considered in this study are operational costs, depreciation of fixed assets, return on capital employed while revenues include financial support, sale of packaging material, subsidies and opportunity costs. On the other hand, variables used are useful life of assets (years), cost of equity, marginal corporate tax, cost of debt, equity in the capital structure, unit costs of refuse collection and other treatment and efficiency of collection of glass, paper/cardboard etc. The results of the economic, environmental and financial analysis revealed that the net cost of packaging waste recycling or management is not being paid by the industry. the analysis suggested that the financial support for the cost of recycling or waste management should be paid or at least covered to some extent by industry to the local authorities. The results of economic analysis (opportunity costs) showed the 128%, 135% and 207% cost coverage of plastic recycling in 2010 in Portugal, Belgium and Italy respectively. These statistics show that the system would still be sustainable if the financial support from green dot companies to local authorities is declined. According to the environmental cost-benefit analysis, it has been analyzed that recycling packaging waste is less costly for the environment than other disposal operations.

In addition, Bassi et al.,(2020) estimated the environmental and economic potential of plastic packaging waste in Italy. This study has been conducted considering the role and effectiveness of extended producer responsibility (EPR) as a key initiative. A total of 40 management scenarios on plastic packaging waste have been generated along with evaluating the environmental and economic performance. An economic analysis has been analyzed using cost-benefit analysis for each stakeholder. The capital expenditure (CAPEX) has been calculated by using annual building and equipment costs along with the installation costs. The formula used for its calculation was CAPEX multiplied by capital recovery factor with interest rate. While, the operating expense (OPEX) indicator used in the economic analysis included the costs of the energy, material consumption (diesel), building the equipment, maintenance and insurance of the building the equipment etc. The data of all economic indicators have been normalized using purchasing power parities (PPP) – World Bank, 2019 and inflation rates (2019). Out of 40 management scenarios, three scenarios affected the economic analysis. First, there was no economic incentive/advantage has been found under the scenario of recycling PET to food-grade granules due to high capital investment. Secondly, the scenario – increasing collection rates significantly increased the quantity of material along with a rise in revenues and losses. Third, economic conditions have been improved for recyclers under the scenario – evaluating a different plastic composition. These findings showed that regular review of profit/loss and recycling methods is necessary.

Further, material flow analysis of plastic packaging management by Lombardi., et al (2021) was conducted in Italy. The study showed that plastic packaging management is one of the major reasons which is responsible for the environment and health. The study showed that Italy has a decent recycling rate, practically 44% and that the energy recuperation and landfill levels are around 40% and almost 17%, respectively. There is space for making plastic waste administration more productive. A portion of the EU-28 nations has significant spaces of progress on account of a lot of plastic bundling in landfills, while others, despite the fact that they present great recycling rates, could handle a few issues in taking on the circular economy approach since they keep on consuming plastic bundling in squander to energy plants.

Similarly, De Lucia & Pazienza (2019) evaluated the attitudes of researching farmers towards the utilization of conventional market-based tools (for example subsidies and tax reductions) as well as different drives, for example, a compensation back instrument under an Extended Producer Responsibility (EPR) to decline the agricultural plastic waste. The study has been conducted in the region 'Foggia' which is perceived similar to the biggest plain in southern Italy using the data of 1,783 farmers and a multinomial regression model to examine the likelihood of embracing the above arrangement instruments. Key outcomes propose that the decision of every strategy device would be impacted by the sort of plastic waste produced. Specifically, plastic bundling and plastic movies would probably influence the likelihood to settle on an endowment. Interestingly, different sorts of plastic waste for the most part created by grain crops exercises (plastic packs and bottles) would lean toward the reception of a tax reduction component. Results also revealed that the probability of opting for a subsidy policy is affected by the production of plastic film, cardboard packaging waste and plastic packaging by 17%, 15% and 12% respectively. Secondly, the probability of adopting tax credit policy significantly increased by using plastic packaging by 8% and 2% by cardboard packaging 15% by plastic waste i.e. bags, bottles etc. A similar research has been conducted by Carascia-Mugnozfitalyza et al., (2007) which estimated the optimization and management of plastic waste in the agricultural sector of Italy. The authors used a geographic information system (GIS) to analyze the production, collection and disposal of plastic.

Other European countries are also efficiently worked on plastic recycling. For example, in Germany, Volk, et al., (2021) examined the mechanical and chemical recycling using the techno-economic and environmental assessment approach is incontestable in a very case study on the usage of on an individual basis collected mixed light-weight packaging (LWP) waste in Germany. Within the recycling methods, the majority of materials polypropene (PP), polythene (PE), polyvinylchloride (PVC), and polystyrene (PS) have been used. The combined mechanical and chemical recycling (pyrolysis) of LWP waste shows hefty saving potentials in GWP (0.48) metric weight unit CO2e/kg input), CED (13.32 MJ/kg input), and value (0.14 €/kg input) and a 16% higher carbon efficiency compared to the baseline state of affairs with state-of-the-art mechanical usage in Deutschland. This results in a combined usage potential between two.5 and 2.8 million metric tons/year that might keep between 0.8 and 2 million metric tons/year in addition within the (circular) economy rather than incinerating them.

For example, the study of Milios et al., (2018)emphasized the increasing plastic production and the high generation of plastic waste. the analysis conducted in this study is based on the plastic waste management flow model which calculated three different types of impacts; economic, environmental and social by using indicators; GHG emissions, costs and benefits (monetary) and the number of jobs created. Results of the economic analysis showed that high domestic plastic recycling increases the net profit (revenue) of 1.2 million EUR/year. This profit is also in-line with the less export of plastic waste because the recycler living abroad can also generate profit by producing the final product. At the same time, the sender in the domestic country can lose the opportunity of generating profit. Further, the results of the social and environmental analysis showed that increasing plastic recycling in Sweeden increases the employment opportunities and savings of greenhouse gas emissions (GHG).

2.2. Economic analysis of Recycling – Arund the globe

Similary, Liu, et al., (2018) analyzed to evaluate the response of circular economy in reference to greenhouse gas emission of Chinese plastic recycling industries. The analysis has been done using an input-output model using IPAT equation and decomposition analysis to assess the GHG emissions reduction benefits. Findings showed that the exluation of circular economy response reduces waste pollution (post-consumer) and also decreases GHG emissions. Results also revealed that a large amount of plastic waste resource and recycling the waste are main factors contributing to the GHG emission reduction. However, there was no significant impact of economic efficiency and technological advancement on GHG emission reduction. Statistics show that China is one of the top ten countries in plastic pollution. Hence, significant research has been done on plastic recycling and its economic and environmental aspects.

Accorsi et al., (2013) presented a case study analysis on the economic and environmental assessment of reusable plastic containers. This study has been conducted in a food catering supply chain by proposing an original framework of design and distribution of food packaging network. The authors considered the flow of fruits and vegetables through the food-catering chain from vendors to customers. The analysis is based on a comparison of the multi-use system to single-use packaging. Single-use packaging includes boxes (cardboard, wooden, disposable plastic crates etc.) by using lifecycle assessment methodology. The advantages of the RPC system for vendors and farmers are highlighted in this economic analysis. The most obvious benefit is the cost savings in package purchases. DC and customers, on the other hand, incur increased costs for traceable transit and handling activities, as well as predicted losses. For this particular volume of food, the implementation of an RPC system would result in a global cost increase of around 69,300€ per year, translating to a cost increase of 0.058€/kg for the supplied items. Results revealed that The use of an RPC system has a lower environmental impact in terms of CO_2 equivalent emissions. The wider economic return, on the other hand, is expected to be negative, resulting in a cost increase of around 0.06€ per kilogram of a handled food product. Due to increasing management overhead, the DC is the chain partner that will bear the bulk of the cost of adoption. Farmers are likely to benefit financially from the implementation of RPC packages.

Shagiakhmetova et al., (2020) investigated the economic efficiency of plastic recycling in plant construction in Kazan by using the discounted method for efficiency, which included different measures i.e. net present value (NPV), internal rate of return (IRR), discounted payback period (PBP) and profitability index of the discounted expenses (PI). The estimated area for analysis included different workshops for cleaning containers, washing, sorting, crushing and melting flakes etc. The estimated model revealed that the project for a plastic recycling plant is highly cost-effective and socially significant. It has also been analyzed that all indexes fulfilled the requirement as at an annual discount rate of 18%, the internal rate of return was 41.6% and the discounted payback period was 4.13 years. The study also concluded that the construction of a plastic waste recycling plant is an efficient solution to environmental issues and is also cost-effective.

In addition, Basuhi, et al., (2021) have analyzed the environmental and economic implications of post-consumer plastic waste management in the United States. The analysis has been conducted by considering three scenarios; energy recovery, mechanical recycling and fuel recovery while using the process-based treatment models. Authors found that a business-as-usual rise in collection volume alone will not be sufficient to balance GHG emissions and will not be economical. They have also quantified the potential found in improving waste-to-energy efficiencies, developing high-yield plastics-to-fuel pathways and incorporating design for recycling. From an economic analysis, external market factors such as the sale price of electricity, fuels and virgin pitches are critical to the financial practicality of treatment processes. The analysis allowed to assess the extent of investment and type of policy endeavors needed to tackle the problem. Investment of 17–21 Billion USD has been estimated to gather and treat 100% post-consumer plastic waste in the United States.

Further, Torkashvand et al., (2021) highlighted plastic usage and its implications along with the cost-benefit analysis. The cost-benefit of plastic solid waste management through the creation of an economic model and the characterization of various scenarios for changing the status of plastic solid waste management. The findings revealed that the study city of Iran generates 8971 tonnes of plastic solid trash each year. Through five specified channels, the plastic solid wastes were eventually delivered to either a recycling or landfilling facility. Post-separation routes accounted for 83 percent of total recycled plastic solid waste, while source separation routes accounted for only 7.7% of total recycled plastic solid waste. The net revenue of plastic solid waste management increases by 334,000 euro per year with the aggregation of post-separation routes while increasing public participation, and the ratio of source separation route raises net revenue by 875,000 euro per year, which is the best economic condition among the scenarios, according to the economic comparison of scenarios.

In Asia, plastic waste generation is one of the main crises. Inadequate recycling infrastructure, unsustainable disposal practices, a lack of recycling awareness, and the continued shipping of huge amounts of waste from industrialized countries to the region hinder efforts to reduce plastic waste in the region. China's 2017 restriction on plastic trash imports exacerbated the problem by driving unsustainable garbage shipment from high-plastic-waste-generating countries like Japan to alternative destinations in Southeast and East Asia. The Japanese government is scrambling to find ways to deal with the growing amount of plastic waste at home. Following China's prohibition on plastic garbage, Malaysia became one of the major alternative destinations. Hence, a comparative analysis by Kuan et al., (2021) showed that both countries Malaysia and Japan faced issues and limitation in landfill capacity and indiscriminate waste disposal.

2.3. Challenges:

Recycling is a process in which companies and authorities have to face multiple barriers and challenges. Paletta et al., (2019) examined the barriers and challenges that occur in plastic valorization with reference to a circular economy in plastic converting companies in Itlay. The findings from this case study revealed the positive and significant relationship between the use (recycling) of used plastic materials and business strategies. It also suggests that high recycling targets cannot be achieved solely by a singular industry. The municipal and regional administrations should support the industries. From an economic point of view, Vogt et al., (2021) explored the challenges that occur due to the quality of materials and methods used in recycling. Plastics' widespread use has been fueled by their mix of low cost and features, however, these characteristics put waste management strategies for plastic recycling in jeopardy. Although certain post-consumer recycling programs have been around for nearly 50 years, a large portion of plastics still winds up in landfills or other disposal schemes. With the rising concerns about plastic waste, particularly ocean plastics, there is a dire need for development and alternative techniques for converting plastic trash into the valuable product(s) that would support their efficient circular application. Some of the specific challenges faced in plastic recycling are waste sorting/separation, the variability of products and high efficiency and low cost. Finally, the commercial success of these different strategies (recycling through mechanical and chemical means) is generally limited by either performance, which includes large variance in key metrics, or economics, where the products can match the performance of virgin materials but the recycling process is costly.

One of the major recent and ongoing challenges faced in the recycling of plastic is the COVID-19 pandemic. Oil prices have a significant impact on the prices of recycled products and, as a result, on plastic recycling programs. Here, Issifu et al., (2021) looked at how the ongoing COVID-19 pandemic is affecting crude oil prices, and how that, in turn, is expected to affect how much plastic gets recycled. Changes in the price of crude oil are a primary driver of the price of recycled plastics, according to the structural vector autoregression's (VAR), impulse response functions and variance decompositions. Results showed that, because plastics are generated from oil by-products, declining oil prices raise the recycling cost. As a result, taxes should be used to support the price of recycled plastics while also encouraging long-term behavioral changes among consumers and producers to collect and recycle protective equipment so that it does not clog waste or end up in our water bodies as plastic waste. Similarly, Silva, et al., (2021) evaluated the comprehensive analysis of increased plastic pollution in the Covid-19 pandemic. It emphasizes that future initiative, whether in response to a public health emergency or not, should strike a balance among health and environmental safety, as the two are inextricably linked. Even though the use and consumption of plastics improved our quality of life, it is critical to change to more sustainable approaches, such as bio-based plastics. The study also suggested that plastics should remain at the forefront of Europe's and the world's political agendas, not just to reduce plastic leakage and pollution, but also to encourage sustainable growth and drive both green and blue economies. There should be involvement of the scientific community, politicians, plastic producers for future implications.

The challenges in recycling process are also being faced by the developing countries. The study of Gunarathne et L., (2019) explored the challenges and opoortunities for the recycling industry in Sri Lanka. Data has been collected in the form of interviews, document analysis and site visits. It showed that various upstream and downstream actors in the recycling value chain (broadly stakeholders), waste system phases, and the enabling environment are all challenges for the recycling business. Sri Lanka has many social, environmental, and economic issues and is far from being a circular economy. Awareness-raising, capacity-building, infrastructure and technology investment, law enforcement and policy execution, international collaboration, private–public partnerships, fiscal policy assistance, and industry formalisation are all necessary responses to these difficulties. As a result, the answers necessitate a multifaceted and multi-stakeholder approach. Liang et al., (2021) analyzed the plastic waste trade and managemnt in Asia. The study revealed that in Asia, plastic waste was predicted to be 79 Mt in municipal solid trash and 42 Mt in industrial solid waste, respectively. Recycling status in the region is highly unsatisfactory. In 2016, Asia imported 74% of the world's plastic trash, with China (mainland) importing the most plastic waste (5.8 to 8.3 Mt) till 2017. In 2017, Asia imported almost half of its plastic garbage from other regions, and after removing the amount exported, 98 percent of the plastic waste was left in Asia for treatment and disposal. In 2018, plastic waste imported by the region decreased by about 72%. Further, There is still a significant difference between the amount of plastic garbage imported into Asia and the amount exported from Asia.

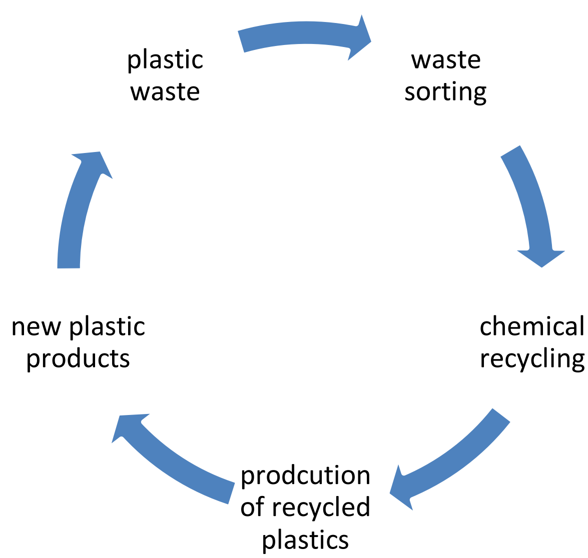
As a result of China's prohibition on plastic trash imports, imports fell to 52 kt in 2018, while exports from the main exporting countries or areas, such as Hong Kong (China), the United States, Japan, and Germany, fell. Between 2016 and 2018, plastic trash imports increased significantly in Vietnam, Malaysia, and other Asian countries and regions. In light of this, Asian governments are beginning to impose tight import restrictions on plastic garbage from other countries.

Plastic pollution has a deep link with economic development. For example, Barnes (2019) used plastic pollution statistics to analyze the relationship between mismanaged plastic waste and income per capita in 151 countries using panel data uncovered empirical evidence for the environmental Kuznets curve. Furthermore, he found evidence for the premise that investing in scientific and technological research is a vital tool for minimizing plastic pollution.

3. Methodology:

For the present study we have created a model that analyzes the process of plastic recycling over time to measure the costs and benefits associated with recycling. The study has focused specifically on the costs and benefits associated with plastic waste recycling to the process of chemical recycling. The process of chemical recycling replaces the virgin hydrocarbons in the process of plastic manufacturing as the chemically recycled plastics have properties similar to virgin plastics (Rahimi & Garcia, 2017). Figure 12 presents the process of chemical recycling within the ambit of circular economy.

Figure 12: Process of chemical recycling



Source: Quantafuel (2022)

The present study focuses on a single plastic recycling firm and weighs the costs and benefits associated with the process of plastic recycling by analyzing the profits made by a single plastic recycling firm. The basic tools of analysis used for this study was financial ratio analysis and Michael Porter's 'five forces industrial analysis' that was conducted on the financial statements issued annually by the firm.

3.1. Quantafuel:

The Quantafuel is a recycling firm that converts plastic waste into low carbon-fuel. This fuel is an alternative to the virgin oil used in the production of plastic products. The process at Quantafuel involves sorting of post-consumer plastic waste, and its recycling. The over-arching framework of the process is built on a circular economy model. The process of collection, sorting and recycling follows a circular value chain. Benefits from the recycling procedure followed at Quantafuel include reduction in wastes in the landfills and avoiding carbon emissions from incineration of plastic waste.

The operation of the company spans over three distinct phases. The first phase last from 2007-2013 which involved R&D activities, the next phase lasted from 2013-2017 where the outcomes of R&D were converted into proof-of-concept industrial scale model, from 2017 onwards production begun (Quantafuel, 2022a). In the first quarter of 2021 (Q1) the first production line started operating at full capacity (Quantafuel, 2022b).

3.2. Data sources:

The data used for the analysis were the annual financial statements issued by Quantafuel. The statements were part of the annual financial reports issued by the firm. These reports were obtained from the firm's official website[1].

3.3. Time period of study:

The firm (Quantafuel) began its production operation in 2017. Therefore, the financial statement for four financial years i.e. the period from 2018 till 2021 were analyzed.

3.4. Financial Ratio analysis:

To measure the profitability of the firm were gauged using the financial ratio analysis. The following ratios were used to analyze the financial sustainability of the recycling business.

[1] Quantafuel's official website: www.quantafuel.com

3.5. Variables description:

This section includes the variables description along with their formulas for the financial analysis to be conducted.

1. Equity ratio:

The equity ratio measures the total assets of company in comparison to the total equity generated by the company. It is a solvency ratio that indicates the proportion of company's assets that are financed by the owner(s) investments. It indicates the sustainability of a business. The equity ratio is important in understanding solvency of the business i.e. the amount of assets owned by the investors. That is the assets attributed to the investors when all the liabilities are paid off.

The equity ratio is calculated by the following formula:

Equity ratio= total equity/total assets

Higher equity ratios indicate the sustainability of a business, as they show higher level of confidence and investment in a business by investors. Moreover, companies with higher equity have lower costs of raising capital through debt, as it avoids the expenditure on interest payments (MAC, 2022).

2. Earnings per share (EPS):

The earnings per share is a measure of the profitability of a business. It is calculated by dividing the net income of a firm (annually or quarterly) by the number of stock shares.

Earnings per share (EPS) = Net income of the company/Average outstanding shares of the company

EPS is the basic ratio used by investors to gauge whether a company is profitable enough for investment since a higher EPS indicates higher profitability. It is also instrumental in determining the share prices of the firm (Bankrate, 2022).

3. Debt-to-Equity Ratio:

The debt-to-equity ratio is a measure of the amount of debt a firm uses to operate (Knight, 2022). This ratio shows the choice business firms make between using debt and shareholder(s) to finance their businesses. It is calculated using the formula:

Debt to Equity Ratio = Total Debt / Shareholders' Equity

A very high Debt to equity ratio may be indicative of financial troubles within the company i.e., unsustainability of the business and an inability to meet its debt obligations (Gall, 2015). Yet on the other hand, a very small debt to equity ratio indicates an over reliance on equity which can be an inefficient (Gall, 2015). Therefore, a financially sound business should have an optimum ratio of debt to equity.

The rule of the higher the better and vice versa doesn't apply to debt-to-equity ratio. In fact, an optimum DE ratio varies from industry to industry (Knight, 2022). Tech based businesses such as recycling which invest a significant amount of capital in R&D activities typically tend to have a debt-to-equity ratio of 2 or below (Gall, 2015).

4. Return on equity (ROE):

The return on equity is a measure of the return on investment. It is calculated by using the formula.

Return on equity = net income/shareholders' equity

An increasing trend in ROE over time indicates that the firm's productivity and profitability is increasing over time. Conversely a declining ROE is a sign of declining productivity (CFI, 2022). Additionally, ROE is also serves as a measure of the competitive advantage when compared to the average for a particular industry (CFI, 2022).

5. **Working capital ratio:**

A working capital ratio is a measure of a business's liquidity and operational efficiency (Maverick, 2021). It is a ratio of the current assets and current liabilities of a firm. It is calculated by the formula:

Working Capital Ratio= Current Assets/Current Liabilities

A high working capital ratio (greater than 1) indicates that business has sufficient assets to meet its short-term debt obligation. A working capital ratio smaller than 1 may result into problems of liquidity for the firm and it may have trouble meeting its short-term debt obligations. A very high working capital ratio on the other hand, is suggestive of the fact that the excess cash held by the firm is not being directed into reinvestment into the company thereby giving up on potential growth (Maverick, 2021). A working capital ratio between1.5 - 2 is considered desirable depending upon the type of industry.

6. **Return on Invested Capital (ROIC)**

ROIC is a profitability index that calculates the ratio of return that a company earns when compared to the invested capital. It shows how efficient is the firm at generating income from the capital it has employed (CFI, 2022b).

It is calculated by considering the cost of the investment and the returns generated. This includes income after taxes but before interest is paid. The value of an investment is calculated by subtracting all current long-term liabilities, those due within the year, from the company's assets.

The formula for the calculating ROIC is:

ROIC = operating profits before interest and after tax/fixed assets+ Net Current Assets

ROIC is an important measure to determine the value of a company. If a firm's more returns compared to the cost of acquiring capital is a value creator. On the other hand, a company who ROIC is equal to or lesser than the cost of capital is value destroyer and does not employ investors' fund in an efficient manner (CFI, 2022b).

Generally, when ROIC exceeds cost of capital by at least more than two percent, the company is deemed as value creator and vice versa. A negative ROIC indicates a business is consuming capital rather than generating return on the invested capital.

7. Return on Assets:

Similar to ROIC, the Return on assets or ROA is also a measure of how efficiently a company generates profits on its assets. ROA reflects a company's financial health as the return on assets compares the value of a business's assets with the profits it produces over time. It is calculated by using the formula:

Return on Assets= Operating Profits/Total Assets

When ROA raises over successive time periods (quarterly or yearly), it indicates the company is profitable and financially sound. Conversely, a deteriorating ROA indicates that the company's profitability is declining (Curry & Birken, 2021).

8. Gross margin:

Gross margin is net revenue after deducting the cost of goods sold (COGS). Companies use gross margin, gross profit, and gross profit margin to measure how their production costs relate to their revenues. It is calculated by using the formula:

Gross Margin = Sales- COGS/Sales

When a company's gross margin is falling, it may strive to slash labor costs or source cheaper suppliers of materials (Bloomenthal, 2022). Alternatively, it may decide to increase prices to increase its revenue.

9. Operating Margin:

Operating margin is a profitability ratio measuring revenue after covering operating and non-operating expenses of a business (CFI, 2022b). It is calculated by using the formula:

Operating Margin= Operating Profit/ Sales

A higher operating margin indicates higher profitability. Negative operating margin on the other hand, indicate that the revenue generated is not covering costs and the business is incurring losses.

10. Net Margin:

The net profit margin is the profit (net income) of a firm expressed as a percentage of its revenue. It is the one the crucial indicators of a company's financial sustainability (Murphy, 2022). It is calculated using the formula:

Net Margin= Net Income/ Sales

By looking at a company's changes net margin over time its profits can be forecasted, moreover, the efficiency of the business model can also be gaugued (Murphy, 2022). By tracking increases and decreases in its net profit margin, a company can assess whether current practices are working and forecast profits based on revenues.

11. Economic Value:

The economic value of a product represents the consumer's willingness to pay for it. Firms use the measure of economic value to set pricing for their products (Banton, 2020). It includes both the tangible as well as the intangible value associated with product. The tangible value is associated with product in terms of its functionality and intangible value such as consumer sentiment (Banton, 2020). It is calculated using the formula:

Economic Value = Net Profit - Cost of Capital

It is believed that the value is created only if the net operating profit exceeds the cost of capital, i.e. EVA is positive (Almasan & Grosu, 2009).

12. Cost of Capital:

Cost of capital is the minimum return that must be attributed to a business in order for capital investment such as the purchase of new equipment to be justified (Hayes, 2021a). It is calculated using the formula:

Cost of Capital = Capital employed*WACC

13. Capital Employed

Capital employed can also refer to the value of all the assets used by a company to generate earnings. It is the total assets of company that are engaged in generating revenue. It calculated by using the formula:

$$\text{Capital employed} = \text{Total Assets} - \text{Current liabilities}$$

An increase in the capital employed indicates that the firms are investing in long-term growth of the business (Hayes, 2021b). Moreover, it also provides an insight into how a company is investing its capital (Hayes, 2021b).

14. Weighted Average Cost of Capital (WACC)

The weighted average cost of capital or WACC is a common way to determine required rate of return (Hargrave, 2022). A higher WACC indicates the high risk associated with a business. A declining WACC on the other hand, indicates financial sustainability. It is calculated using the formula:

$$\text{WACC} = ((\text{Equity}/\text{debt}+\text{Equity})*re)+((\text{Debt}/\text{debt}+\text{equity})*rd(1-t))$$

Where,

Re: Cost of Equity

Rd: Cost of Debt

A company's investment decisions for new projects should always generate a return that exceeds the firm's cost of the capital used to finance the project. Otherwise, the project will not generate a return for investors (Hargrave, 2022).

3.6. Porter’s five forces model: Analysis of European plastic recycling industry

The present study uses the framework of porter’s five force analysis to measure the profitability of plastic industry of Europe and Quantafuel’s business operations. The company mainly carries out its operations in Europe as of 2022 (Quantafuel, 2022). The analysis includes Quantafuel’s rivals within the European plastic recycling industry. A brief description of the theoretical framework and elements involved in porter’s five forces analysis is given in the following sub section.

3.6.1. Porter's Five Forces Framework

It a method of analyzing the industry environment within which a business operates. The fundamentals of the model’s derive from industrial organization economics to determine the competitive intensity of an industry which makes investment in an industry (business) profitable (Wikipedia, 2022).

According to Michael Porter, who first introduced the model in Harvard business review in 1779, there are five forces that represent the key sources of competitive pressure within an industry (Porter, 1998). These are:

a) Threat of New Entry:

A firm’s profitability is linked to barriers to entry for new firms into the industry. When entry into an industry is easier, a profitable industry attracts more firms thus enhancing competition and driving down profits for a firm. The threat of new entry into industry is inversely linked to the costs of entry for a new firm and the time required to break even.

b) Supplier Power:

The power of suppliers refers to the ability of supplier of raw materials to manipulate (drive up) the costs of inputs. The key determinant of supplier power is number of suppliers of raw material. Similar to competition in market of finished products the market power of suppliers is inversely related to the number of suppliers of an input, as it gives the firm’s ability to drive down costs and enhance profitability. Another factor that can increase supplier power is the uniqueness of input such as a particular variety of wheat etc.

c) Buyer Power:

The ability of buyers to drive price down can also impact the profitability of a business directly. In case of monopsony (a single buyer and many sellers) the buyer has complete price setting power, but as the number of buyers increases the firm's profitability enhances.

d) Threat of Substitution:

The threat of substitutes is inversely linked to the profitability of firm within an industry. An industry with low product differentiation and availability of many close substitutes will be less profitable when compared to an industry with high product differentiation and no close substitutes.

e) Competitive Rivalry:

A large number of competitors in an industry decreases the profitability of a particular firm within the industry. This is due to the fact with each additional rival a firm's market share and consequently its market power goes down. A firm with virtually no rivals in an industry (a monopoly) will have the greatest profitability when compared to a perfectly competitive firm which has very small market share and virtually no market power.

Figure 13: Porter's five forces framework

Source: Harvard business review, 1979

4. Results and Discussion

This chapter presents the results of the financial ratio analysis conducted on the financial statements of Quantafuel. Prior to explaining the results, a brief summary of the important financial statements of the company i.e. the consolidated income statement and the consolidated statement of financial position are presented in Table 1 and 2.

Table 1: Consolidated income statement

Income statistics of Quantafuel				
	2018	2019	2020	2021
Operating revenue	223650	497	8387	5161
Operating profit (loss)	-35791	-52104	-127714	-186885
Net financial items	-15388	-17372	-324897	193403
Profit (loss) before tax	-51179	-69476	-470611	6518
Income tax expense	-30403	-30924	-31702	-10401
Net Profit (loss) for the period	-81582	-100400	-502313	-3883
Items that maybe reclassified to profit (loss)	-92343	404	1342	2184
Total comprehensive income for the year	-81582	-99996	-500972	-1699

Source: Quantafuel

*Figures expressed in NOK thousands (000's)

The table 1 shows the income of Quantafuel for the period of 2018-2021. The firm has incurred net loss during the study period. However, it has been able to shrink its losses significantly over time. The net loss for has shrunk to only 3.88 million NOK from the net losses 81.5 million NOK in 2018. Consequently, total comprehensive income of has risen to a negative 1.69 million NOK. This indicates that the business is gaining efficiency over time.

Table 2: Consolidated statement of financial position

Financial statistics of Quantafuel				
Assets	**2018**	**2019**	**2020**	**2021**
Total non-current assets	109440	429839	788129	1151653
Total current assets	94474	167234	708917	348518
Total assets	203914	597073	1497046	1500171
Equity and liabilities				
Equity attributed to the owner of the parent	92672	211310	572261	1068479
Total equity	107695	278090	653987	1068479
Total non-current liabilities	47191	223258	705712	303711
Total current liabilities	49028	95725	137347	127981
Total equity and liabilities	203914	597073	1497046	1500171

Source: Quantafuel

*Figures expressed in NOK thousands (000's)

The Table 2 displays the financial position of the company over time. It shows that the total equity of the company has increased over time.

4.1. Financial Ratio Analysis:

A financial ratio analysis was conducted to gauge the profitability of plastic recycling using Quantafuel as a case study. The results of the analysis are displayed in Table 3.

Table 3: Results of Financial ratio analysis

Financial ratio Analysis				
	2018	2019	2020	2021
Equity ratio	0.53	0.47	0.44	0.71
Earnings per Share (EPS)	-	-1.1	-4.15	-0.03
Debt-to-Equity Ratio.	0.89	1.15	1.29	0.40
Return on Equity (ROE)	-0.76	-0.36	-0.77	-0.0015
Working Capital Ratio	1.93	1.75	5.16	2.72
ROIC	-0.32	-0.14	-0.11	-0.13
ROA	-0.18	-0.09	-0.09	-0.12
Gross Margin	0.60	-0.73	-0.77	-11.53
Operating Margin	-159.8	-104.8	-15.2	-41.9
Net Margin	-364.2	-201.2	-59.8	-0.4
Economic Value	1496378	-804107	9940691.153	-
Capital Employed	-49028	501348	1359699	-
Cost of Capital	-1577960	703707.2	-10443004.15	-
WACC	32.18	1.40	-7.68	-

Source: Author's compilation from Quantafuel annual reports (2018-2021)

4.1.1. Equity ratio

The company's equity ratio for the year 2018 is 0.53. This means that investors rather than debt funded more assets. 53% percent of the company's assets are owned by shareholders and not creditors. Over the next two years i.e. 2019 and 2020 the equity ratio fell below 0.50 as evident by the table 3. However, by 2021 there was recovery in the company's equity ratio, as it rose to 0.71, indicating that the majority assets of the company were owned by the shareholders. The high equity ratio also indicates the shareholder's confidence who view the firm as worthy of investment.

4.1.2. Earnings per share

Earnings per share for the company have been negative indicating the losses incurred by the company. The negative income of the company means that the company is losing money. However, in the year 2021 earnings per share increased to -0.03 NOK indicating a recovery in the company's losses.

4.1.3. Debt to equity ratio

The debt-to-equity ratio for the company has been high for the years 2019 and 2020 (a greater than one debt to equity ratio indicates a debt larger than the total equity generated by the company). However, the debt was to equity was significantly reduced in the year to only 0.40. This indicated a significant increase in equity as indicated in Table 3.

4.1.4. Return on equity

Yet another measure of the profitability of a company is the return on equity ratio (ROE). The return on equity has been negative from 2018 till 2020. However, in the year firm has managed to overcome the negative return on investment to a significant degree with an ROE of -0.7 in 2020 to an ROE of -0.0015 in 2021. This shows a significant improvement in the income of the firm.

4.1.5. Working Capital Ratio

The firm has had a very high working capital ratio from the benchmark values of less than 2. The working capital ratio has been the highest in 2020 (5.16) indicating excess cash flow which was not reinvested in the business. In 2021 the dropped to 2.16 indicating a positive change.

4.1.6. Return on Invested Capital (ROIC)

The value of Quantafuel is gauged by using the ROIC. The Table 3 shows the ROIC has been negative. Since a negative ROIC indicates a business is consuming capital rather than generating return on the invested capital. This shows that Quantafuel has not been able to generate any returns on investments and is still in the cash burning phase of its operations. However, its losses have shrunk in 2021 when compared to 2018 as ROIC was -0.32 in 2018 as opposed to -0.13 in 2021.

4.1.7. Return on Assets (ROA)

The return on assets has also been negative for the period under study as indicated in table 3. This indicates that the company has not been able to generate profits over the four-year period and its financial viability is declining over time.

4.1.8. Gross Margin

The gross margin has been positive for 2018 (0.6) meaning thereby it retained a portion of its sales revenue. However, from 2019 to 2021 the gross margin has been negative. This indicates that the sales revenue was smaller than the cost of goods due to expenditures incurred in expansion on plant and purchase of shares in its plants in UK and Skive.

4.1.9. Operating Margin

The operating margin has also been negative throughout the study period. However, the position of operating margins has improved over the study period due to expansion in sales revenue. The operating margin was -159.9 in 2018. However, it shrunk to merely -41.9 as the sales revenue increased.

4.1.10. Net Margin

The net margin for the company was also negative for the period as it has not generated any profits. However, the net margin ratios shows that the company has been able to recover its losses and improve its financial condition over time.

4.1.11. Economic Value

Economic value is created only if the net operating profit exceeds the cost of capital. Since for the period under analysis the net operating profits have been negative as shown in the Table3. Therefore, the net economic value has also been negative. This employs that the shareholders' value is not created, but depleted, meaning that the firm does not generate enough profit to cover the cost of invested capital.

4.1.12. Capital Employed

The capital employed is used as an estimate of the assets of a company. There has been a significant increase in the capital employed for the company over the period under study as indicated in table 3. This indicates that the assets of the company (in the form of plant and equipment etc.) have increased significantly over time and the operational capacity has expanded.

4.1.13. Cost of Capital

The negative cost of capital for the year 2018 and 2020 indicate that the firm paid less than the borrowed capital possibly in the form of deferred interest payments.

4.1.14. Weighted Average Cost of Capital (WACC)

The WACC for the year 2018 was very high (32.18) indicating the high risk associated with the business. The WACC has declined significantly over time indicating a higher improved financial viability of the business.

4.2. Discussions:

The above-mentioned results show the company's performance for last four years. The negative values of earnings per share (EPS) indicates the loss company is facing. However, the decline (from -1.1. in 2019 to -0.03 in 2021) in that negative value shows the improvement in company's performance.

The increase in equity ratio from 0.53 (2018) to 0.71 (2021) shows that the number of company's assets held by shareholders increased. It indicates a rise in shareholder's confidence in the company. On the other hand, a decline in negative values of return on equity (annual return) also shows the improvement in company's income as ROE measure the business profitability for investors and owners. Similarly, debt to equity ratio results indicates the higher value of debt than equity of the company.

The analysis also includes the capital-related ratios like working capital ratio, return on invested capital (ROIC), capital employed and cost of capital. The results of the working capital ratio for the years 2018 (1.93) and 2019 (1.75) shows that Quantafuel is making enough and effective use of its assets as these values are between 1.2 - 2.0. However, the values for the years 2020 (5.16) and 2021 (2.72) shows that company might not be making efficient use of the capital. It shows that it is maintaining huge amount of assets (short-term) rather than investing its funds to generate enough revenue. While the decline from 5.16 to 2.72 shows a significant and positive change. Similarly, the return on invested capital, a profitability ratio shows how good is company at allocating capital and for generating profits. Negative values of this ratio shows that company is in loss and is not allocating enough capital.

The results shows that there has been a significant increase in the capital employed. In 2018, the value of capital employed (plant, equipment) is negative (-49028) mainly because the company was recently founded in 2017. Hence, the positive and increasing values of this ratio 501348 (2019) and 1359699 (2020) shows the significant contribution to company's situation of these years. Further, the negative cost of capital ratio for year 2018 and 2020 indicates that firm has paid less than the borrowed capital. In addition to cost of capital, the value of weighted average cost of capital (WACC) also shows that company is trying to improve its performance despite the high associated risk factors.

The values of gross margin and net margin shows that over the selected time period, company has been improving its performance. The value of gross margin in 2018 was 0.6 showing that company retained enough portion of its sales revenue. But in years 2019 and 2020, sales revenue seems to be smaller than the cost of goods/services due to high expenditure on expanding its business in UK and Skive.

Similarly, the negative operating margin also shows that company has not generated profits but the improvement in the statistics shows that company can perform well in upcoming years if it keeps on expanding its sales and generates enough revenue and profits. Lastly, Economic value is created only if the net operating profit exceeds the cost of capital. Since for the period under analysis the net operating profits have been negative as shown in the Table3. Therefore, the net economic value has also been negative. This employs that the shareholders' value is not created, but depleted, meaning that the firm does not generate enough profit to cover the cost of invested capital.

4.3. Porter's five forces industrial analysis

Porter developed a model which shows the relationship between industry and consumer goods in 1974 which was then modified in 1979a to discuss the profitability of industries. Further, porter (1979b) presented the model in the form of diagram showing the association between five forces and how these forces affect the industries and their profitability (Watanabe, 2018). In this analysis, the strengths and barriers are analyzed which the industry and the company must face.

Michael porter's five forces industrial analysis was applied to analyze the profitability of the European plastic industry and targeted firm (Quantafuel) of the present study. Since Quantafuel operates within Europe, the industrial boundary was set to the plastic recycling industry in Europe. The section 4.2.1 contains a brief description of plastic recycling industry in Europe followed by Quantafuel's comparison to its industry rivals on each of Porter's forces of competition.

4.3.1. Plastic recycling industry in Europe

According to Plastics Recyclers Europe (PRE) the total installed capacity of plastic recycling stood at 9.6 million tons with 960 plastic recycling facilities in 2020 (Plastic Recyclers Europe, 2022). The plastic recycling industry had a total turnover of 7.7 billion euro in 2020 (PRE, 2022). Italy and German alone accounted for one third of the total installed capacity. Due to legislative support, advancement in sorting and recycling technologies, the plastic recycling activities in Europe grew by 60% from 2017-2020 as evident from the figure (PRE, 2022). The PRE has further projected that the installed capacity within Europe will triple by 2030. As of 2020, 600 plastic recycling firms operated within EU (PRE, 2020)

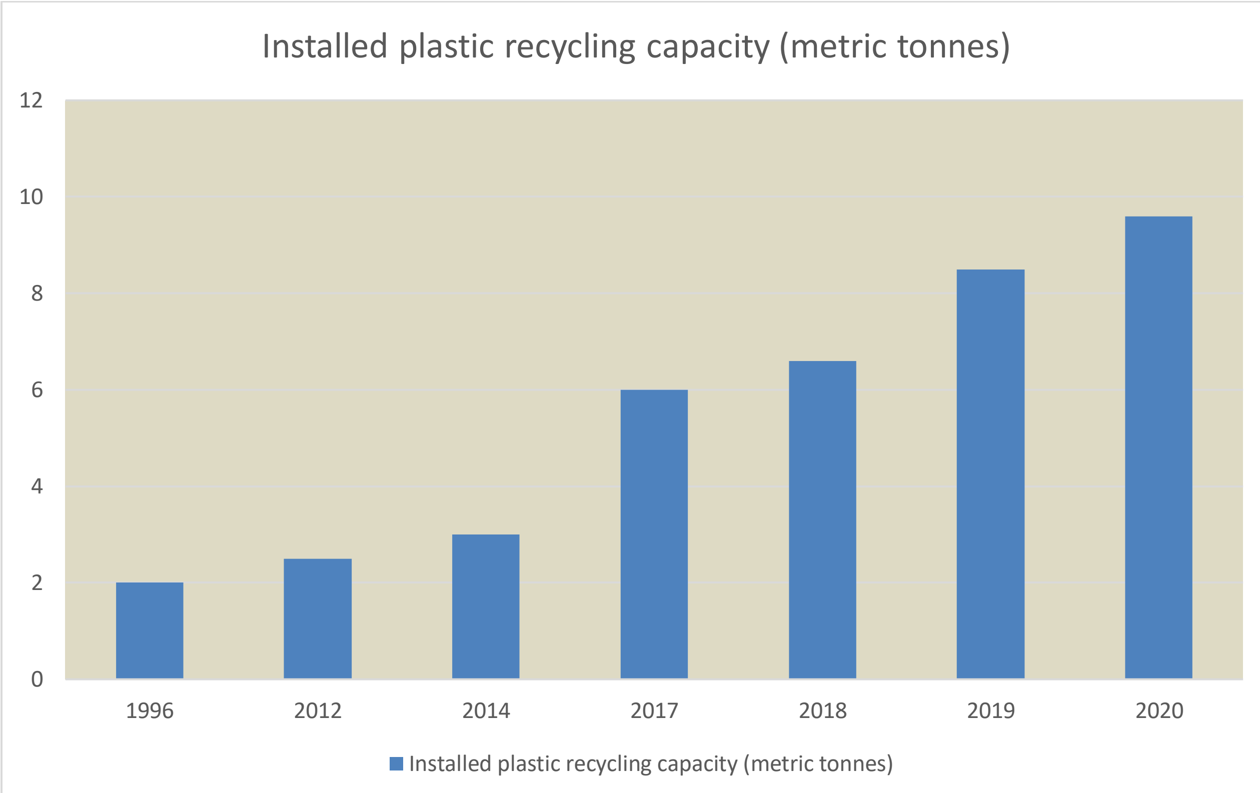
4.3.2. The impact of porter's five forces of competition on plastic recycling industry in Europe and Quantafuel

The impact of each one the porter's five forces on the Quantafuel's profitability are analyzed in the following sub-sections. The impact of the competitive forces is categorized into low, moderate and high.

I. Threat of new entrants

The threat of new entrants to the industry is very high. This is evident from the fact that the installed capacity of plastic recycling within Europe is increased by 60%, from 2017-2020 (PRE, 2022).

Figure 14: Installed plastic recycling capacity in Europe (1996-2020)



Source: PRE (2020)

Above figure shows the installed plastic recycling capacity has been increased over the passage of time which showed that there is a high threat of new entrant in in the industry. For any new company which is going to start a new plastic recycling plant must face multiple barriers and threats.

First, the choice of the product type is an important thing to look for entry in an industry. For example, the entry in the polyethylene market is easy because it has some common production activity. While on the other hand, the entry in halogen free flame retardant-based compounds is quite difficult due to technical procedures and know-how. Secondly, there is a difficulty with bureaucracy, choosing the right country is critical. Many southern countries, such as Greece and Italy, have bureaucratic challenges when it comes to obtaining a company's authorization. The Northern European countries have a strong environmental policy, which places an expensive burden on the corporation in terms of antipollution technology. Third, with an increasing competition, a company should be innovative while producing its product as there are strict policies considering copy rights and patents. Fourth, the knowledge about economies of scale is essential for entering the industry as these are the cost advantages that owner must obtain. Economies of scale refers to the situation where company's amount of output is measured per unit of time. It includes increasing rate of return, decreasing rate of return and constant rate of return (Voulgaris).

Moreover, the Capital requirements the industry are also very high as evident from the investment on plant (assets) in Quantafuel's annual reports issued from 2019-2022. The company also scored high on the metric of Access to latest technology as the company has to incur high risk in terms of project risk as the Skive plant of the firm used a unique pyrolysis technology where the risk of robustness of operations and quality of output (Quantafuel, 2020).

The firm also scored high on the measure of Experience and learning effects, as Quantafuel took 13 years before first line was fully operational in Q1 2021. The plastic recycling business had very high R&D costs. Quantafuel invested 500,000 NOK in R&D activities during the financial year 2018 that were received from Enova and Innovasjon Norge (Quantafuel, 2019).

The Government policies favorable to new entrants as part of EU carbon neutral vision (PRE, 2022). The European Union in July 2018 revised its legislative framework on waste. The revised targets aimed at reducing the amount of waste going to landfill to no more than 10% by 2035; an EU target for recycling 65% of packaging waste by 2025 and 70% by 2030; and a recycling target of 55% for plastic packaging. Moreover, under the extended producer responsibility (EPR) modulated fees are proposed. This which means producers pay for a lower fee for products that are easy to reuse or recycle and higher fees for products that are more difficult to handle (Milios et al.,2017).

The cumulative impact of these metrics show that Quantafuel is at a high risk of competition from new entrants.

II. Bargaining power of suppliers:

The bargaining power of supplier is generally investigated by looking at supplier concentration, volume relevance to suppliers, input differentiation, and industry switching costs. The availability of multiple suppliers and low switching costs are two factors that eliminate supplier power.

There are many small businesses with a wide range of product differentiation. Because of the large range of applications for plastic in a variety of fields, there is also a wide range of demand. There are also some companies that produce a product that has a wide range of applications. Lastly, there are companies that create two or more related products that are used as raw materials by another company to make a final product. Suppliers of raw materials (substances), on the other hand, benefit from compliance with the REACH chemical regulation, an advantage that can function as a barrier to external (non-EU) rivals in some situations (Voulgaris). Because of the high number of small, medium and large firms and increasing demand, the suppliers have high trading control with high bargaining power **(Research dive).**

Figure 15: Cycle of Porter five force's method

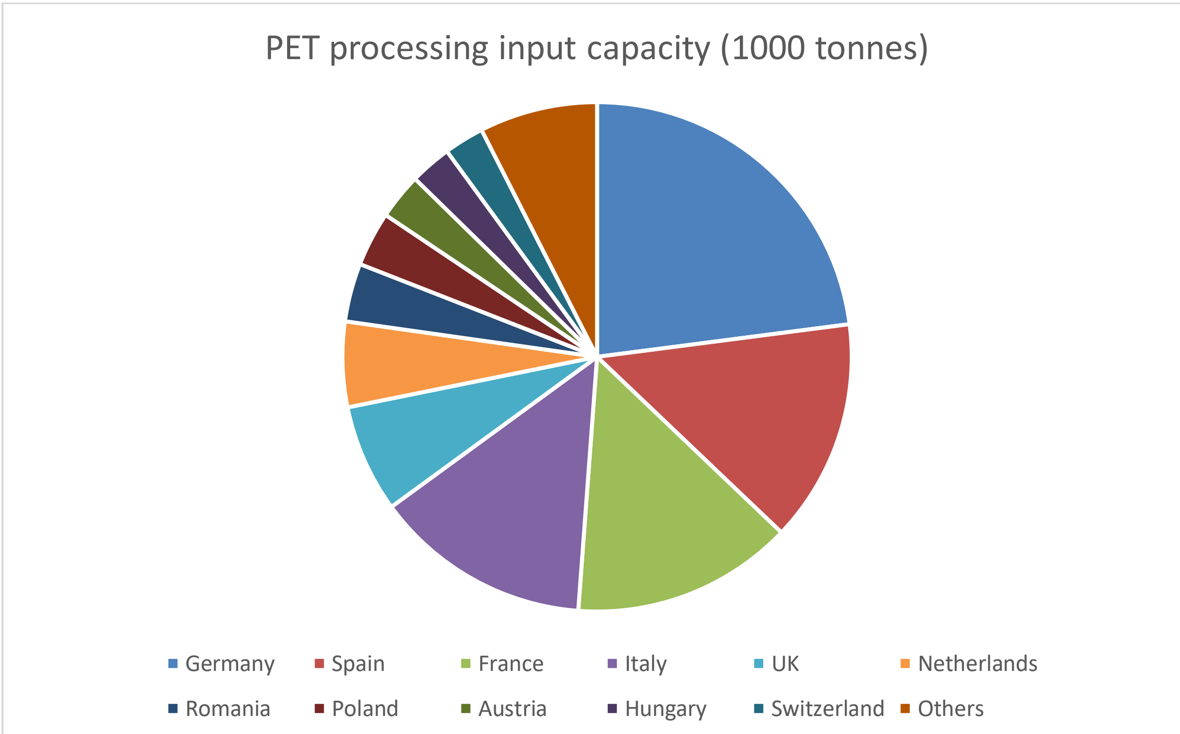
Suppliers are pushing for the increase in input prices, delivery times, in changes in quality and quantity supplied, due to the very rapidly growing demand of recyclable plastic scrap. This is due to increase in installed capacity within Europe (PRE, 2022). This directly translates into increased bargaining power of scrap plastic supplier thereby enhancing the competition within the plastic industry and for Quantafuel. However, due to low product differentiation as the Pyrolysis technology used for chemical recycling used by Quantafuel does not require the strict sorting which was needed with earlier recycling technologies (Quantafuel, 2022a). Thus, there is little uniqueness of supplier's products or services (differentiation) and therefore low cost associated with Switching cost for supplier's products yet another factor that contributes to power of bargaining power is the risk of exchange rate fluctuations. Quantafuel deals in various European currencies, and it has not hedged against the risk making it vulnerable to the risk (Quantafuel, 2022a). Therefore, the impact of this competitive force is moderate.

III. Bargaining power of buyers

The major European countries i.e. EU28+2 plays an important and significant contribution towards plastic recycling. The PET statistics shows that within the EU28+2, Germany (23%) is followed by France (14%), Italy (14%), and Spain (14%) is responsible for 65% of the PET reprocessing capacity (Petcore Europe, 2022). PET consumption across applications increased, resulting in a net demand of 5.1MT in Europe in 2020. Around 1.3 million tonnes of recycled PET were used to meet this need. Beverage bottles account for 47 percent of total PET consumption in the EU, according to Zero Waste Europe (ZWE) (Cole, 2022).

The below figure 16 shows the PET processing input capacity in 1000 tons of top European countries. The figure shows that Germany, Spain, France, Italy and UK are the top five countries for highest PET processing capacity which shows the high demand for recycling withing these countries.

Figure 16: PET processing input capacity in Europe



The bargaining power of buyers has decreased due to increase in demand for recycled plastic has increased drastically during the last decade within Europe (PRE, 2022).

In the EU, total converter demand for LDPE/LLDPE is around 17%, and when combined with PP and HDPE, two other polymers from the polyolefins group, they account for roughly 50% of overall demand. The demand for PE film among EU converters has been steady over the last decade, at roughly 9 million tonnes (PRE, 2019). With the rapid and significant increase in buyer volume (number of customers) the competitive pressure on Quantafuel has eased up. This force thus has a low impact on industry competitiveness and therefore on the profitability of Quantafuel.

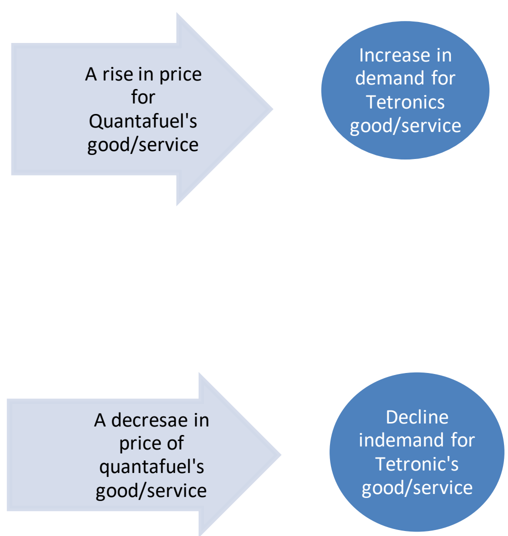
Hence, the analysis shows that European plastic recycling industry has bargaining power in its hand. However, the industry is facing multiple challenges like consumer pressure to increase recycled content in products is rising. In addition, there is a question that do the recycling industry collect and sort enough quantity and quality of pet for recycling as demand for rPET increases?

In addition to the increasing demand, the collection, sorting and processing PET trays and other waste material to help meet overall pet demand is another key challenge that the industry has to face (Petcore Europe, 2022).

IV. Threat of substitute products or services

In plastic recycling industry, the price elasticity of one type of plastic product is affected by other type of plastic product. The more substitutes are available, the less worth will be of one company's product. The substitution effect is major player in a perfectly competitive market. For example, Quantafuel's one of the top competitors is Tetronics technologies. Quantafuel is a chemical product manufacturer that specializes on energy. Tetronics is a corporation that specializes in environmental waste treatment and material recovery methods. Let's suppose both of these companies produce same product or service and same prices.

Figure 17: Substitution effect



In this example, we have taken two companies Quantafuel, which is our main target company. The second company is Tetronics, which is Quantafuel's one of the top competitors **(Craft, 2020).** Both of these companies provide plastic recycling services. The above figure shows the substitution effect in plastic recycling industry. The above figure 13 shows that according to the substitution effect, if the price of Quantafuel's goods/services increases, the demand for Tetronics will increase. Conversely, there will a decline in demand of Tetronic's goods/services with a decline in Quantafuel's goods/services.

Similarly, in the packaging or plastic recycling industry, the comparison is between the products whose price is quite closer to each other's. Not between the products whose prices have huge difference i.e., plastic containers and metal containers, logistics and transportation as plastics are light weight. Although, there are some industries in which there are no threats because no other material can be used except plastic i.e. medical industries.

Thus, there is a high degree of substitutability for the products of Quantafuel as one of the most widely available substitutes was virgin plastic. Therefore, the perceived level of product differentiation was extremely low thus adding to competitive pressure on Quantafuel.

V. Rivalry among existing competitors

Rivalry is the most common yet an important factor among competitors in an industry. Plastic recycling in Europe has been evolved rapidly over the passage of time. The rivalry among competitors is high as there are nearly 600 producers of recycled plastics in Europe according to PRE indicating a high number of competitors.

However, Quantafuel effectively reduced competition through horizontal integration by acquiring 100% ownership in Quantafuel Skive ApS as well as Quantafuel UK in 2021. Through vertical integration by acquiring 40% shares of Germinor AS a leading business of waste trading logistic and sorting. Therefore, the risk of this competitive force is low.

5. Plastic Recycling in Italy

The plastics industry started in 1861 when the first semi-synthetic was developed. Later, many plastics, including PVC and cellophane, were created in the first half of the 20th century, and research into the composition and characteristics of polymers started around the same time. The Solvay facility in Rosignano Marittimo (Livorno) was inaugurated in 1914. Then, based on the utilization of oil as a raw material, the modern plastics industry was formed in the 1930s. Società Italiana Resine, an Italian corporation, was established in Milan in 1931. It was the first business to start making polymer-based resins and moulding powders. Due to the economic boom and rapid rise in consumption after 1963, about 38 plants, the national refining capacity was over 180 million tonnes annually, approximately 30% of the total capacity in Europe. Further, 18 refineries in Italy continued to be operational in the 1990s, producing about 100 million tonnes annually21. EniChem, Solvay, and Shell purchased the entire chemical division of Montedison. The latter was combined with Basf to form Basell. Versalis was created in 2012 from the merger of ENI's production facilities for styrene and elastomers. Italy produced 77.6 million tonnes of refinery products in 2019, of which 7% were naphtha (ECCO, 2022).

Italy is the second-largest plastic consumer in Europe. In 2020, it used 5.9 million tonnes of polymers derived from fossil fuels, or roughly 100 kg per person1. In Italy, packaging accounts for 42% of all plastic consumption. Products in this industry are often disposable and have a limited lifespan. 1.9 million tonnes of fossil-based polymers, primarily polyolefins like polyethylene (PE) and polypropylene (PP), but also polystyrene (PS), and polyamides (PA), were produced in Italy in 2020. Italy has many “compounders”, companies that buy polymers and additives to then mix them to produce polymer compounds for specific uses. Around 5.8 million tonnes of polymers were processed in Italy's robust plastics manufacturing industry in 2020. there were roughly 5,000 companies in this industry, employing 110 thousand people, and making an annual revenue of about €15 million. The Italian industry is a major exporter of machines which recorded a surplus of €2 billion despite Covid-19 issues in 2020 (ECCO, 2022.)

The total installed capacity of the plastic recycling in Italy was recorded to be 9.6M tons with a facility of 960 recycling companies, according to Plastic Recyclers Europe (PRE). The total turnover of the plastic recycling industry was 7.7 Billion euros in 2020 (PRE, 2022). One third of the total installed capacity was accounted to the Germany and Italy. The recycling rate increased by 60% from 2017-2020 in Europe due to legislative support, as they were able to progress in sorting and achieving latest recycling technologies.

The PRE foresee that it is expected for the plastic waste recycling to be increased by a tripped capacity by 2030, and 600 companies are already working within Europe as of 2020. Since the 60% increase in 2017-2020 has been a remarkable number, the EU carbon neutral vision may enter the govt. policies to favour the new entrants. The plastic recycling market of Italy in 2020 was standing at 2.05M tons and it is expected to raise to 3.51M tons by March 2030 with a strong CAGR of 5.6% till 2030. The marine life in the nearby areas of Italy has become seriously disturbed due to plastic waste leading to an increased demand in the plastic waste recycling. This has fueled the market growth during the forecast, and it will hopefully continue to grow.

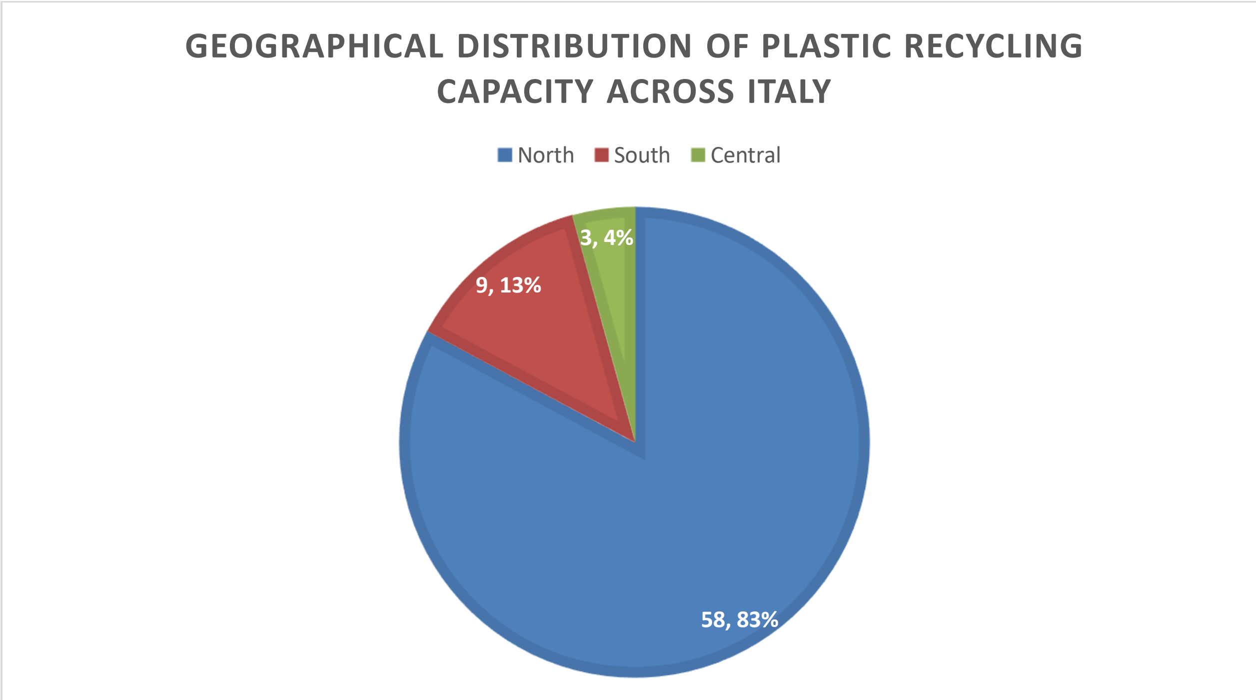
Moreover, the Malayan govt. has also asked to stop the illegal transport of the plastic waste from Italy to Malaysia. This will trigger an increase in the plastic waste recycling in Italy, in turn climbing the growth rate of the plastic waste recycling market. Versalis is an Italian chemical company which introduced a project in 2020. In that project a newer technology was proposed to recycle the plastic waste chemically, along with converting mixed waste plastic as a feedstock for new polymers through pyrolysis.

There have been many investments made by major stakeholders, which is likely to augment the demand of plastic waste recycling in the coming years. The plastic demand was exponentially increased in Italy during the COVID-19 pandemic, but the waste disposal was inappropriate due to limited labor force, therefore, negatively affecting its recycling. Nevertheless, it is expected of the plastic waste recycling industry to resile with rigorous efforts and measures taken by the government and the adoption of the projects by the end user companies. This data is based on a real time basis to add new movements by the industry, however it does not limit itself to the temporary disruptions, plant announcements or shut downs (ChemAnalyst 2021).

Geographical Distribution of Plastic Recycling Capacity across Italy:

There are more than five hundred under plastic recycler across Italy. The largest among them (in terms of revenue) are largely concentrated in the northern region of the country. The pie chart below displays the distribution of the seventy largest plastic recycling companies across northern, central and southern Italy.

Figure 18: Geographical Distribution of Plastic Recycling Capacity across Italy



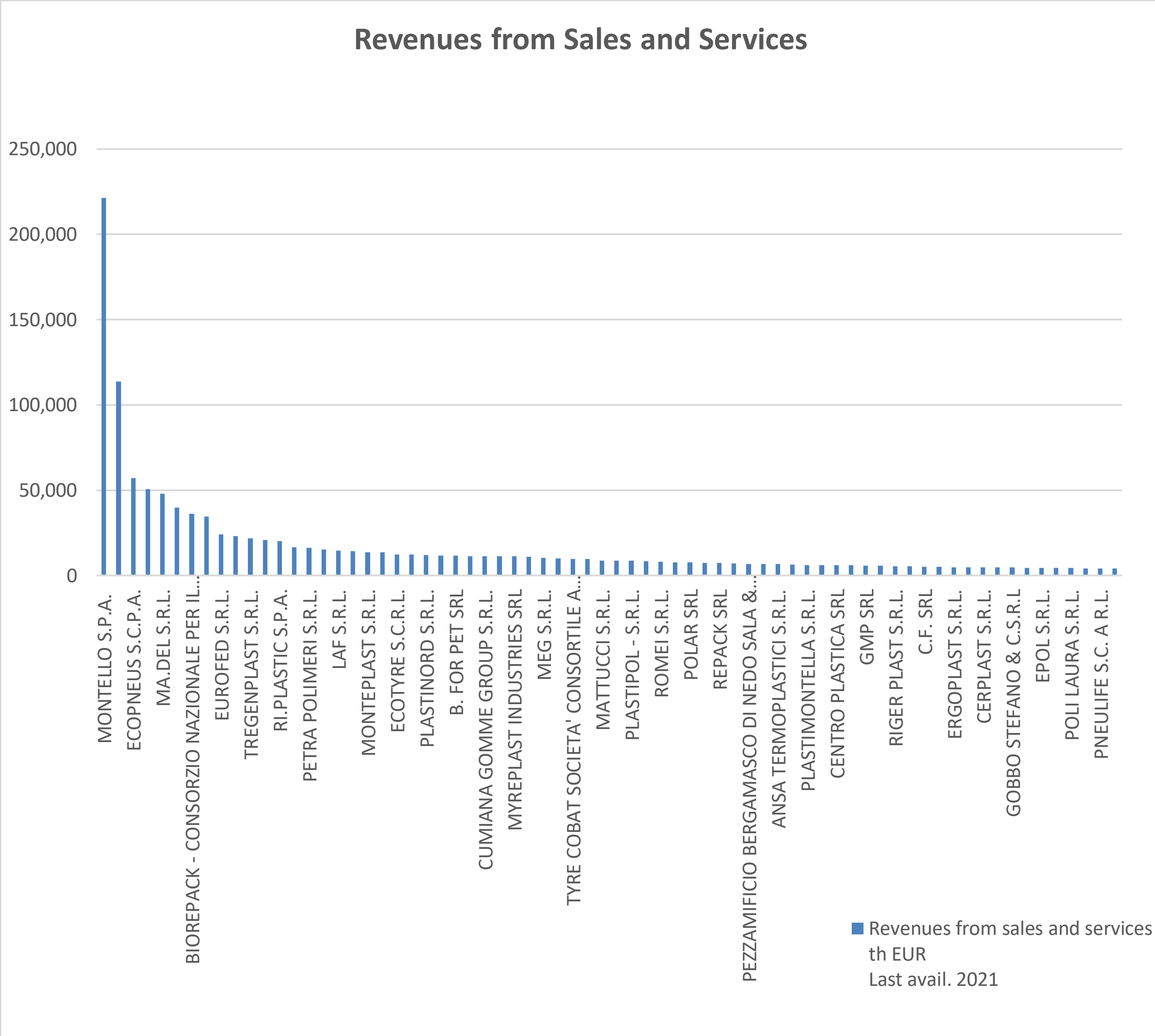
Source: AIDA

The figure 18 shows that more than half i.e. 83% of the large plastic recyclers are located in Northern Italy. Only 13% are located in southern Italy. While only a very small percentage i.e. only around 4% is located in central Italy. Thus, it can been seen that the plastic recycling capacity is not uniformly distributed across Italy but concentrated overwhelmingly in the north.

Distribution of Total Market Revenue Among the Largest firms in the industry:

The distribution of the total industry revenue is displayed in the figure below. The figure displays the distribution of industry revenue among the 70 largest firms (with annual revenue of more than 4 million euros). The trend across the industry shows that the industry has only a single very large firm i.e. Montello S.P.A., which is followed by a fringe of large to medium firms. However, the overall industry revenue is scattered across hundreds of smaller firms.

Figure 19: Distribution of Total Market Revenue Among the Largest firms in the industry

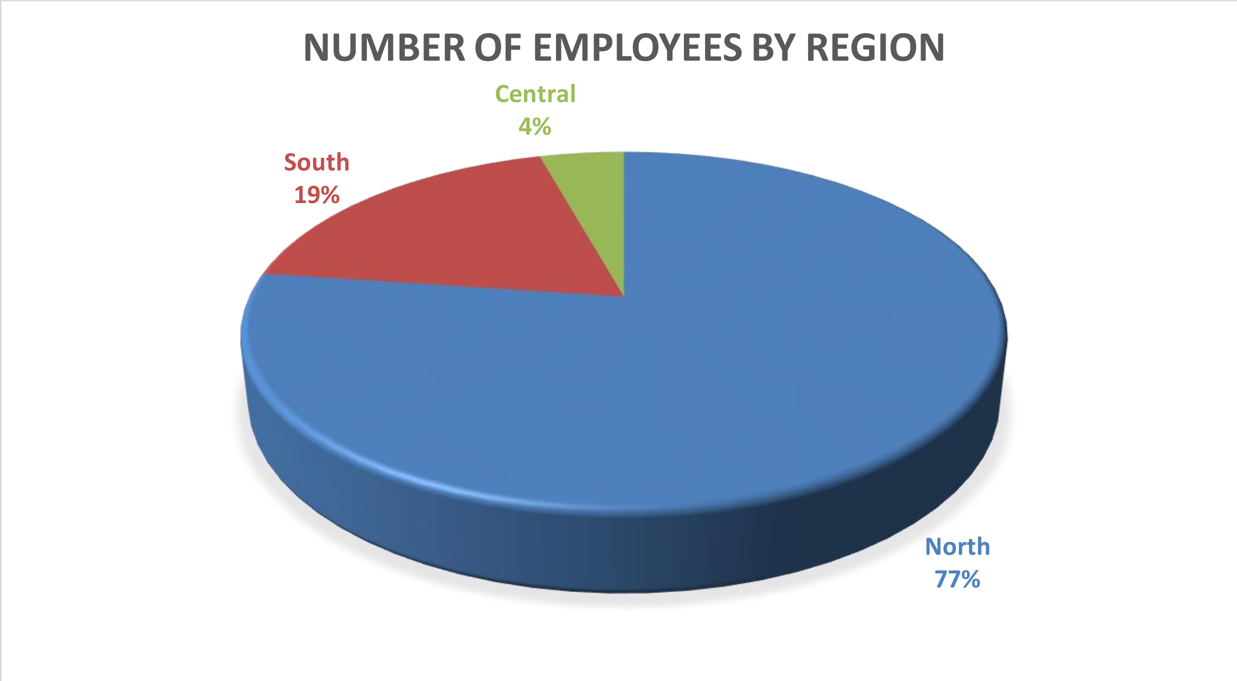


Source: AIDA (2022)

Geographical Distribution of Employment in the Plastic Recycling Capacity across Italy

The figure below displays the geographical distribution of workers engaged in the plastic recycling industry for seventy largest recyclers in Italy i.e. having the an annual revenue of more than 4 million euros.

Figure 20: Geographical Distribution of Employment in the Plastic Recycling Capacity across Italy



Source: AIDA (2022)

Similar to the trend in installed capacity (discussed above), the employment in plastic recycling industry is also concentrated largely in the northern regions of the country. However, compared to 83% of firms being located in north the total workforce employed is only 77%. On the other hand, southern regions of the country despite having only 13% of the total installed capacity engages 19% of the work force. This hints at the possibility of automation at the larger plants located in the northern parts of the country. The central parts of the country have consistent ratio of installed capacity and workforce employed.

Employment is the main factor which contributes to growth of any sector. The overall industry's revenue over the past decades has been fluctuating in Italy and in the Europe as mentioned in the figure 21. Italy's plastic packaging goods sector is expected to generate €10.1 billion in revenue by 2022, placing it second in Europe (of 24 total EU countries). The sector's position (2nd) hasn't changed since 2017. It ranks as Italy's 74th-largest industry in 2022. (of 209 total industries that IBISWorld tracks). Since 2017, the sector's ranking (74th) has not changed.

Figure 21: Plastic Packing Goods Manufacturing Industry Revenue (%) - Italy vs. Europe

Source: IBISWorld (2022)

The plastic problem therefore has multiple facets, and as a result, there is neither a single solution nor is it straightforward. It requires a sophisticated approach that can exploit synergies to tackle the issues of pollution and decarbonization simultaneously. Hence, Italy has been working around key objectives of; reduction in plastic consumption, an increase in recycling and reuse rates and the use of bioplastics. First, plastic consumption should be reduced in the main consumers of plastics which are packaging, automotive and construction sectors. Secondly, a rise in recycling rates will decrease emissions and imports of carbon dioxide intensive materials. Third, for uses where current options are insufficient, plastics derived from plant-based basic materials are one potential answer to environmental issues. In this regard, On January 1st, 2011, the Italian law prohibiting plastic shopping bags went into effect. It prohibits the use of regular plastic shopping bags and requires the use of biodegradable bags instead. This rule has contributed to the substitution of the polymer (polyethylene PE) that is often used in the manufacture of these bags with biodegradable polymers as well as the reduction in the overall consumption of these bags.

To achieve these goals, policies are needed to control production and consumption, together with polymer standards to promote recyclability. To retain Italian industry's competitiveness, maintain jobs, and ensure that businesses adapt their operations to meet long-term carbon neutrality goals, action must also be taken on the demand side. This entails developing a market and a need for bio-based plastics and secondary raw materials, for instance by including unique requirements in public procurement contracts (ECCO, 2022).

6. Coclusion and Policy Recommendations

The economic analysis shows the past and future profitability of the firm or industry. In present study, the economic analysis has been done on one of Europe's top plastic recycling firms "Quantafuel" founded in 2017. The analysis has been done into two parts separately (i) financial ratio analysis (ii) porter's five industrial analysis. The data has been taken form the official website of Quantafuel while the porter's five analysis is based on the overall plastic recycling industry of Europe followed by the Quantafuel's market analysis.

First, the financial ratio analysis included the fourteen different ratios to analysis the company's performance. These ratios are equity ratio, earnings per share (EPS), debt-to-equity ratio, return on equity (ROE), working capital ratio, return on invested capital (ROIC), return on assets (ROA), gross margin, operating margin, net margin, economic value, capital employed, cost of capital and WACC. The results of this financial analysis showed the overall gauge, profitability, and financial stability of the company over the selected time period. The results shows that profit is negative as the company is in the initial phase of industrial operation. Most of the investment is being done on the acquiring plants and equipment.

Indicators are negative in absolute values, but they are becoming smaller as the company is recovering losses slowly as the operational capacity is increasing. In Q1 2021, the first line of production became fully operational. In q1 2022 the entire first plant became fully operational.

In 2018 company was not performing well internally we need to analyze why is it not performing well in 2018 despite of having good economic growth in the country. In 2019 compnay has improved its financials but the economy was in downward trend we can that rate of equity was low so there should be some reason for company's poor performance in 2019. In 2020 company was performing wonderfully financially. They increased their assets which can reflect on capital employed but due to market crash in the country of Norway it has heavily affected the company. The rate of equity was -6.8 %. Therefore, we need to find what was the reason for 2020 poor performance. Overall, in financial standpoint of view the company is trying to improve its financial conditions which can be seen on capital employed on assets. Hence, the company is affected by external factors which needs to be addressed.

Secondly, the Porter's five forces analysis showed that plastic industry in Europe and our targeted company Quantafuel have been significantly affected by the five forces i.e. threats of new entrants, bargaining power of suppliers, bargaining power of buyers, threats of substitute products or services, and rivalry among existing competitors. However, the evolving plastic industry is overcoming through challenges it has been facing.

7. References

Accorsi, R., Cascini, A., Cholette, S., Manzini, R., & Mora, C. (2014). Economic and environmental assessment of reusable plastic containers: A food catering supply chain case study. International Journal of Production Economics, 152, 88-101.

Aida. (2022). Italian company information and business intelligence. Retrieved from Aida: https://login.bvdinfo.com/R0/AidaNeo

Almasan, A & Grosu, C. (2009). The usefulness of the process approach for value creation in the telecom sector. Accounting and Management Information Systems. 8. 521-537.

Andrady, A. L., & Neal, M. A. (2009). Applications and societal benefits of plastics. The Royal Society, 1977–1984.

Bankrate (2022). Retrieved from https://www.bankrate.com/glossary/e/earnings-per-share/#:~:text=What%20is%20earnings%20per%20share,its%20shares%20of%20stock%20outstanding.

Barnes, S. J. (2019). Understanding plastics pollution: The role of economic development and technological research. Environmental pollution, 249, 812-821.

Bassi, S. A., Boldrin, A., Faraca, G., & Astrup, T. F. (2020). Extended producer responsibility: How to unlock the environmental and economic potential of plastic packaging waste?. Resources, Conservation and Recycling, 162, 105030.

Basuhi, R., Moore, E., Gregory, J., Kirchain, R., Gesing, A., & Olivetti, E. A. (2021). Environmental and economic implications of us postconsumer plastic waste management. Resources, Conservation and Recycling, 167, 105391.

Baton, C. (2020). Economic Value. Retrieved from https://www.investopedia.com/terms/e/economic-value.asp

BBF. (2022). Plastic Applications. Retrieved from British Plastic Federation: https://www.bpf.co.uk/plastipedia/applications/Default.aspx#:~:text=Plastic%20is%20used%20across%20almost,and%20electronics%20and%20industrial%20machinery.

BBF. (2022). Plastic Applications. Retrieved from British Plastic Federation: https://www.bpf.co.uk/plastipedia/applications/Default.aspx#:~:text=Plastic%20is%20used%20across%20almost,and%20electronics%20and%20industrial%20machinery.

Bloomenthal, A. (2022). Gross Margin. Retrieved from https://www.investopedia.com/terms/g/grossmargin.asp

Bogert, S., & Morris, J. (1993). The economics of recycling. Resource Recycling, 12, 76-76.

CFI (2022 b). What is ROIC. Retrieved from https://corporatefinanceinstitute.com/resources/knowledge/finance/what-is-roic/

CFI (2022c). Operating Margin. Retrieved from https://corporatefinanceinstitute.com/resources/knowledge/accounting/operating-margin/

Chanda, M. (2021). Chemical aspects of polymer recycling. Advanced Industrial and Engineering Polymer Research, 4(3), 133-150.

Chen, J. (2022). Profitability Index. Retrieved from https://www.investopedia.com/terms/p/profitability.asp#:~:text=The%20profitability%20index%20(PI)%20is,investment%20amount%20in%20the%20project.

Chemanalyst. (2021). Italy Plastic Recycling Market Analysis: Plant Capacity, Production, Operating Efficiency, Demand & Supply, End-User Industries, Distribution Channel, Regional Demand, 2015-2030. Retrieved from ChemAnalyst: https://www.chemanalyst.com/industry-report/italy-plastic-recycling-market-513

Cole, H. (2022). Plastics Recyclers Europe reports a 13% increase in installed plastics recycling capacity. Retrieved from Packaging Europe: https://packagingeurope.com/news/plastics-recyclers-europe-reports-a-13-increase-in-installed-plastics-recycling-capacity/8198.article

Corporate finance institution (2022a). What is return on equity? Retrieved from https://corporatefinanceinstitute.com/resources/knowledge/finance/what-is-return-on-equity-roe/

Crowley, D. (2020). 6 Challenges Facing Plastics Manufacturing in 2021. Retrieved from SYSCON: https://www.syscon-intl.com/plantstar/blog/challenges-facing-plastics-manufacturing

Curry, B. Birken, E.G. (2021). Understanding return on Assets (ROA). Retrieved from https://www.forbes.com/advisor/investing/roa-return-on-assets/#:~:text=Return%20on%20assets%20(ROA)%20is,evaluate%20a%20company's%20financial%20health.

De Lucia, C., & Pazienza, P. (2019). Market-based tools for a plastic waste reduction policy in agriculture: A case study in the south of Italy. Journal of Environmental Management, 250, 109468.

De Sousa, F. (2021). The role of plastic concerning the sustainable development goals: The literature point of view. Cleaner and Responsible Consumption, 3.

Denissen, W., Winne, J. M., & Du Prez, F. E. (2016). Vitrimers: permanent organic networks with glass-like fluidity. Chemical science, 7(1), 30-38.

ECCO. (2022). Plastics in Italy A Vice or a Virtue? Technical, ECCO Climate . Retrieved 2022, from https://eccoclimate.org/wp-content/uploads/2022/04/Plastics-in-Italy.pdf

EUROPARC. (2018). A European Strategy for Plastics in a Circular Economy. Retrieved from EUROPARC Federation : https://www.europarc.org/wp-content/uploads/2018/01/Eu-plastics-strategy-brochure.pdf

Fernando, J. (2022). Retrieved from https://www.investopedia.com/terms/i/irr.asp#:~:text=The%20internal%20rate%20of%20return,same%20formula%20as%20NPV%20does

Ferreira, S., Cabral, M., da Cruz, N. F., Simões, P., & Marques, R. C. (2017). The costs and benefits of packaging waste management systems in Europe: the perspective of local authorities. Journal of Environmental Planning and Management, 60(5), 773-791.

Gallo, A. (2015). A fresher on Debt to equity ratio. Retrieved from https://hbr.org/2015/07/a-refresher-on-debt-to-equity-ratio

Gradus, R. H., Nillesen, P. H., Dijkgraaf, E., & Van Koppen, R. J. (2017). A cost-effectiveness analysis for incineration or recycling of Dutch household plastic waste. Ecological Economics, 135, 22-28.

Gunarathne, A. D. N., Tennakoon, T. P. Y. C., & Weragoda, J. R. (2019). Challenges and opportunities for the recycling industry in developing countries: the case of Sri Lanka. Journal of material cycles and waste management, 21(1), 181-190.

Hayes, A. (2021a). Cost of Capital. Retrieved from https://www.investopedia.com/terms/c/costofcapital.asp#:~:text=Cost%20of%20capital%20represents%20the,preferred%20or%20existing%20capital%20structure

Hayes, A. (2021b). Capital employed. Retrieved from https://www.investopedia.com/terms/c/capitalemployed.asp

Hornberger, L. (2003). Surviving in the plastics recycling industry. Progress in Rubber Plastics and Recycling Technology, 19(2), 77-92.

IBISWorld. (2022). Plastic Packing Goods Manufacturing in Italy - Industry Statistics 2008–2027. Retrieved from IBISWorld: https://www.ibisworld.com/italy/industry-statistics/plastic-packing-goods-manufacturing/1205/

Issifu, I., Deffor, E. W., & Sumaila, U. R. (2021). How COVID-19 Could Change the Economics of the Plastic Recycling Sector. Recycling, 6(4), 64.

Kaminsky, W. (2000). Plastics, recycling. Ullmann's encyclopedia of industrial chemistry.

Knight, J (2006). Financial intelligence.

Kuan, S. H., Low, F. S., & Chieng, S. (2022). Towards regional cooperation on sustainable plastic recycling: comparative analysis of plastic waste recycling policies and legislations in Japan and Malaysia. Clean Technologies and Environmental Policy, 24(3), 761-777.

Lee, W. T., Bobbink, F. D., van Muyden, A. P., Lin, K. H., Corminboeuf, C., Zamani, R. R., & Dyson, P. J. (2021). Catalytic hydrocracking of synthetic polymers into grid-compatible gas streams. Cell Reports Physical Science, 2(2), 100332.

Liu, Z., Adams, M., Cote, R. P., Chen, Q., Wu, R., Wen, Z., ... & Dong, L. (2018). How does circular economy respond to greenhouse gas emissions reduction: An analysis of Chinese plastic recycling industries. Renewable and Sustainable Energy Reviews, 91, 1162-1169.

Lombardi, M., Rana, R., & Fellner, J. (2021). Material flow analysis and sustainability of the Italian plastic packaging management. Journal of Cleaner Production, 287, 125573.

MAC (2022). Equity ratio. Retrieved from https://www.myaccountingcourse.com/financial-ratios/equity-ratio

Mandal, S. A. N. T. A. N. U. (2011). Porter's five forces analysis of the Indian plastic industry. International Journal of Multidisciplinary Research, 1(7), 294-316.

Maverick, J.B. (2021). The Working Capital Ratio and a Company's Capital Management. Retrieved from https://www.investopedia.com/ask/answers/041015/what-does-low-working-capital-ratio-show-about-companys-working-capital-management.asp

Milios, L., Esmailzadeh Davani, A., & Yu, Y. (2018). Sustainability impact assessment of increased plastic recycling and future pathways of plastic waste management in Sweden. Recycling, 3(3), 33

Murphy, C.B. (2022). Net Profit Margin. Retrieved from https://www.investopedia.com/terms/n/net_margin.asp

Our world in data. (2022). Global Plastic Production. Retrieved from https://ourworldindata.org/grapher/global-plastics-production

Our World in Data. (2022). Global Plastic Waste by Disposal . Retrieved from Our world in data: https://ourworldindata.org/grapher/global-plastic-fate

Paletta, A., Leal Filho, W., Balogun, A. L., Foschi, E., & Bonoli, A. (2019). Barriers and challenges to plastics valorisation in the context of a circular economy: Case studies from Italy. Journal of Cleaner Production, 241, 118149.

Pandey, U., Stormyr, J. A., Hassani, A., Jaiswal, R., Haugen, H. H., & Moldestad, B. M. E. (2020). Pyrolysis of plastic waste to environmentally friendly products. Energy Produc Manage in the 21st century IV: The Quest for Sustain Energy, 246, 61-74.

Patrício Silva, A. L., Prata, J. C., Walker, T. R., Duarte, A. C., Ouyang, W., Barcelò, D., & Rocha-Santos, T. (2021). Increased plastic pollution due to COVID-19 pandemic: Challenges and recommendations. Chemical Engineering Journal, 1-9.

Petcore Europe. (2022). Pet Market in Europe State of Play. Retrieved from https://www.petcore-europe.org/news-events/409-pet-market-in-europe-state-of-play-2022.html

Plastics Europe. (2019). PEP Annual Report . Retrieved from https://plasticseurope.org/pl/wp-content/uploads/sites/7/2021/11/PEP_Annual_report_2019_updated.pdf

Porter, M.E. (1979). How Competitive Forces Shape Strategy. Harvard Business Review

Porter, M.E. (2008). The Five Competitive Forces That Shape Strategy. Harvard Business Review

PRE . (2018). Flexible Polyethylene, Accelerating the Transition Towards Circular Economy. Retrieved from https://www.plasticsrecyclers.eu/_files/ugd/dda42a_5e1c67451b2f49adaa79a00afa045f06.pdf

PRE . (2019). Flexible Polyethylene Recycling in Europe, Accelerating the transition towards circular economy. Retrieved from Plastic Recyclers Europe: https://plastics-recyclers-europe.prezly.com/flexible-polyethylene-recycling-in-europe-accelerating-the-transition-towards-circular-economy

PRE. (2022). Publications. Retrieved from Plastic Recyclers Europe: https://www.plasticsrecyclers.eu/downloads

Quantafuel. (2022). Retrieved from Quantafuel.com: https://www.quantafuel.com/

Research dive. (2020). Plastic Recycling Market, by Recycling Process (Mechanical, Chemical), Material (Polyethylene Terephthalate (PET), High-Density Polyethylene (HDPE), Low-

Density Polyethylene (LDPE), Polypropylene (PP), Others), Regional Analysis (North America, Europe, As. Retrieved from https://www.researchdive.com/download-sample/173

Rahimi, A., García, J. Chemical recycling of waste plastics for new materials production. Nat Rev Chem 1, 0046 (2017). https://doi.org/10.1038/s41570-017-0046

RTS. (2020). The Complete Plastics Recycling Process. Retrieved from RTS.com: https://www.rts.com/blog/the-complete-plastics-recycling-process-rts/

Sasse, F., & Emig, G. (1998). Chemical recycling of polymer materials. Chemical Engineering & Technology: Industrial Chemistry-Plant Equipment-Process Engineering-Biotechnology, 21(10), 777-789.

Sattlegger, L., Stieß, I., Raschewski, L., & Reindl, K. (2020). Plastic Packaging, Food Supply, and Everyday Life. Nature and Culture, 15(2), 146-172.

Scarascia-Mugnozza, G., Sica, C., & Picuno, P. (2007, October). The optimisation of the management of agricultural plastic waste in Italy using a geographical information system. In International Symposium on High Technology for Greenhouse System Management: Greensys2007 801 (pp. 219-226).

Scuderi, E. (2021). Towards a plastic-free economy: the Italian plastic tax.

Shagiakhmetova, E., Medyanik, Y., Gimadieva, L., Vakhitova, D., & Yarullina, I. (2020, July). Economic efficiency of plastic recycling plant construction. In IOP Conference Series: Materials Science and Engineering (Vol. 890, No. 1, p. 012114). IOP Publishing.

Silva, A. L. P., Prata, J. C., Walker, T. R., Duarte, A. C., Ouyang, W., Barcelò, D., & Rocha-Santos, T. (2021). Increased plastic pollution due to COVID-19 pandemic: Challenges and recommendations. Chemical Engineering Journal, 405, 126683.

Simon, C. M., & Kaminsky, W. (1998). Chemical recycling of polytetrafluoroethylene by pyrolysis. Polymer Degradation and Stability, 62(1), 1-7.

Thakur, M. (2022). NPV examples. Retrieved from https://www.wallstreetmojo.com/npv-examples/

Thompson, R. C., Moore, C. J., Saal, F. v., & Swan, S. H. (2009). Plastics, the environment and human health: current consensus and future trends. The Royal Society, 2153–2166.

Torkashvand, J., Emamjomeh, M. M., Gholami, M., & Farzadkia, M. (2021). Analysis of cost–benefit in life-cycle of plastic solid waste: combining waste flow analysis and life cycle cost as a decision support tool to the selection of optimum scenario. Environment, Development and Sustainability, 23(9), 13242-13260.

Uekert, T., Pichler, C. M., Schubert, T., & Reisner, E. (2021). Solar-driven reforming of solid waste for a sustainable future. Nature Sustainability, 4(5), 383-391.

Vogt, B. D., Stokes, K. K., & Kumar, S. K. (2021). Why is recycling of postconsumer plastics so challenging?. ACS Applied Polymer Materials, 3(9), 4325-4346.

Volk, R., Stallkamp, C., Steins, J. J., Yogish, S. P., Müller, R. C., Stapf, D., & Schultmann, F. (2021). Techno-economic assessment and comparison of different plastic recycling pathways: A German case study. Journal of industrial ecology, 25(5), 1318-1337.

Voulgaris, C. (n.d.). THE EUROPEAN PLASTIC INDUSTRY ANALYSIS BASED ON PORTER'S FIVE FORCES. THE EUROPEAN PLASTIC INDUSTRY ANALYSIS BASED ON PORTER'S FIVE FORCES. UNIVERSITY OF KENTUCKY. Retrieved from https://pdf4pro.com/amp/cdn/the-european-plastic-industry-university-of-kentucky-4f048d.pdf

Watanabe, M., Cruzetta, A., & Camilo, S. P. O. (2018). Competitiveness of plastic manufacturers: An analysis under the Porterian vision in South of Brazil. Business Management Dynamics, 8(4), 1.

World Population Review. (2022). Plastic Pollution by Country 2022. Retrieved from World Population Review: https://worldpopulationreview.com/country-rankings/plastic-pollution-by-country