WILL WE BE ABLE TO USE RECYCLED PLASTICS OR SHALL WE DECIDE FOR PACKAGING FREE PRODUKCTION?

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This research was supported by the project, which has received funding from the Institute of Technology and Business. Grant Number IVSUZO001 "Benchmark of the world economy in the context of the principles of the circular economy and determining the value of the company.

Abstract: Recycled plastic and its use are imperative for preserving the environment, including proper plastic wash-out. Will we ever be able to push the Czech population and firms to use recycled material? Or is it happening spontaneously? A questionnaire created on Google Forms involves ten legislative and motivational questions comprising relevant data on the amount of plastic in municipal waste between 2010 and 2020 from the Czech Statistical Office. We found that the population understands the importance of using recycled material and recycled plastic without the government's impulse. Despite the high capital intensity, the state should impose taxes to protect the sustainable environment. We suggest a comprehensive and in-depth survey to acquire more accurate data.

Keywords: Recycling, sorting, secondary raw material, recycling cycle, LCA, PET

1 Introduction

Ecology has recently become the number one topic, seeing all global organizations adopt various climate conventions, including protection against environmental pollution. Industrial zones are the top global polluters, churning out multiple industrial companies and their products – plastic [1]. LCA (Life cycle assessment) involves a reliable method of determining decisive factors behind pollution, using software to evaluate data applied by companies to their manufacturing processes. If the LCA shows spectacular results in cutting oil extraction, why the Czech Republic lags in recycling despite ranking among the fifteen best waste-sorting countries?

Burgess et al. [2] suggest that if domestic waste sorting should factor in better recycling, we must adopt the following four measures: standardization (materials, kerbside collection, waste sorting), investments in the infrastructure, business model development throughout the supply chains and making high-value recycled materials. A nationwide solution to plastic waste disposal heavily depends on preserving the value of discarded plastic, profoundly cutting plastic pollution.

Although the Czech economy offers powerful inducements for using recycled plastic, only companies pursuing ecologic goals have adopted this strategy.

Currently, more than 80% of plastic waste is recultivated or burnt, leaving only 20% for recycling. Such a dramatic loss of precious material causes increased pollution levels, preventing effective plastic waste disposal. Material recycling involves an efficient method of plastic waste recycling, requiring a decent separation technique.

Poor waste plastic recycling has recently been ailing the world, calling for a thorough plastic washout. Enterprises involved in plastic recycling focus heavily on raw materials, where even a small number of contaminants significantly worsen quality ratios of secondary polymers (density, strength, or liquidity), leaving stains or re-granulate [3]. Removing insoluble impurities of various natures demands coagulants and flocculants. Failure to develop a unified theory of using coagulation agents and optimal operating parameters of the secondary water treatment carries excessive consumption of agents with no technological or economic profit. At the same time, most enterprises choose water treatment parameters (agent concentration, temperature, or coagulation time) on an empirical basis. A wise choice of the number of agents allows for maximizing the water treatment effect, meeting the requirements for residual concentration in the recycled water. The issue of water treatment optimization needs our attention since the coagulants and flocculants depend on various factors. Probabilistic-determinism planning allows scientific optimization of water treatment and eliminates exorbitant agent expenses [4].

Massive media coverage on environmental plastic pollution and a ban on importing plastic waste in some countries have brought the issue to global attention. The EU recycles only about one-third of plastic waste, leaving the rest for energy use and landfilling [5]. Chemical recycling has recently become an efficient method of achieving the EU's ambitious goals, opening new waste streams for recycling, and generating precious raw materials for the chemical industry. Although there is no legal definition of chemical recycling, experts agree that it involves transforming plastic polymers into monomers or chemical elements. Chemical recycling includes techniques like gasification, pyrolysis, liquefication and solvolysis. So far, the chemical industry has not seen many facilities for chemical recycling. The proposed article suggests various processes on the examples of (previously) operated machinery, assessing their ability to recycle plastic. Only a few plants for chemical recycling are in permanent operation, making any evaluation insufficient for the lack of evidence on ecological and economic benefits [6].

Heavy consumption and non-degradability see PET as a primary source of waste piling up at dumpsites that jeopardize our planet [7]. Efficient chemical recycling methods safeguard the environment by cleaning off dumps, saving natural resources and energy and producing chemical substances with added value as main constituents or side products [8].

Global plastic waste generation has been alarmingly growing for several decades. Traditional landfilling and incineration may cause air pollution and a waste of good soil. Scientists try to recycle plastic waste by mechanical, biological, and chemical procedures to ensure sustainability, from which the latest can transmogrify plastic waste into high-quality products like refinery raw materials, fuels, and monomers. Solvolysis, pyrolysis or gasification are specific chemical reactions depending on a solvent, catalyst, or product [9].

The EU has adopted a circular economy, aiming to regenerate the environment. Italy, the largest European fruit and vegetable LCA exporter, makes shipping boxes from recycled plastic. Tua et al. [10] argue that long-used, returnable EURO pallets would be great for shipping. Schwarz et al. [11] claim that effective secondary plastic recycling needs proper washing and sorting, cutting the European emissions by 73% in the event of the fifteen most used plastics.

Plastic materials are cheap, light, durable, and easy to roll into various shapes and applicable products. That is why its production has increased in the last sixty years. On the flip side, its extensive use and poor disposal harm the environment. Plastic production involves about 4% of the global non-renewable oil and natural gas extraction, and 3-4% ensures energy for its manufacture. Many annually produced plastics go to disposable packaging or short-life products lasting up to one year. The current plastic use is not sustainable. Enduring polymers prevent the decomposition of discarded short-life plastics that rapidly accumulate in biotopes. Recycling can lessen the impact of plastic pollution, imposing remedial measures in the current plastic industry. When performed correctly, it can reduce oil consumption and carbon dioxide emissions and help implement responsible waste disposal. Plastic has been recycled since the 1970s, according to its type and uses in different localities. Recycling packaging materials has recently seen rapid development in many countries. Advanced technologies and data collection systems, sorting and reprocessing recyclable plastic allow exploring new ways of recycling. Joining the forces of the public, industry, and governments, we can remove most plastic waste from landfills for recycling [12].

Packaging waste is a crucial part of the total European waste. Modern mechanical recycling systems process mainly rigid boxes (e.g., bottles), paying little heed to flexible materials - foil bags. Current technologies of mechanical foil recycling are outdated and insufficient to treat complicated waste left from consumed flexible plastic (PCFP). The resulting poor quality regranulate is then lacking for complex foil material reuse. The presented study explores the technical and economic value of the upgraded mechanical recycling process (additional sorting, hot wash or upgraded extrusion) – PCFP. The successful material application in plastic injection and film production reflects the quality of the four regranulate types. The regranulates rich in polyethene in the extruded foil is more flexible (45 – 60%), ductile (27 – 55%) and have increased tensile strength (5 – 51%), unlike traditional mechanical recycling methods. Equally, injected samples are more flexible (19 – 49%), ductile (7 – 20 times) and have increased tensile strength (1.8 – 3.8 times). Experts then compare the increased market value and required capital investments, revealing that the upgraded recycling process raises the economic value by 5 – 38%. The study shows how to boost the PCFP mechanical recycling quality and protect the environment, breaking new ground for efficient, unconventional recycling methods [13].

People have recently been thinking about lessening plastic consumption and safeguarding the environment. In the 1980s, nobody thought oceans would be infested with 250 m m3 PET bottles until 2025 [14]. The global society subconsciously safe the planet for future generations, considering waste sorting the fundamental thing. However, simple the issue might appear, economic viewpoints raise the devil. Although all municipalities may boast of sorting skip bins, the rest of the process is uncharted waters of eternal landfilling. Waste treatment companies have a cheap way of waste management, recycling only a small number of plastics for research purposes.

The submitted study aims to determine optimal conditions for Czech companies and households to use plastic recycled materials. We fulfilled the objective with the least capital and ecological burden.

We formulated the following research questions:

Can we commonly use recycled materials upon adopting relevant legislation?

How can we push the Czech people to pick a more expensive, yet eco-friendly option over a cheaper and adulterating one?

2 Literature research

Recycling is a continuously established strategy that goes hand in hand with the economic aspects of business [15]. Therefore, the Society of the Plastics Industry has established codes 1-6 for different types of plastics. The given codes facilitate easier unification of plastics recycling [16]. The most widely-used recycling method is chemical recycling. However, this method largely deforms the plastics, which means that the recycled material has a limited range of application. Nevertheless, further innovation of this method and addition of plant fibres in the recycled material could increase its applicability [17].

Global plastics production and consumption has been growing at an alarming rate in recent decades. Similarly, the accumulation of ubiquitous and durable plastic waste in landfills and in the environment has increased as well. The social, environmental and economic problems associated with plastic waste and pollution require immediate and decisive action. The main current recycling processes are focused mainly on mechanical recycling of plastic waste; this process, however, is also constrained by the need for sorting and/or treatment of plastic waste and plastics degradation during this process. An alternative to mechanical recycling processes is chemical recycling of plastic waste. Effective chemical recycling would enable producing raw materials for various uses, including fuels and chemical materials that could replace petrochemical products.

Chemical recycling is considered an attractive path leading to the reduction of waste and emissions of greenhouse gases, as well as the support of circular economy. In the EU, the readiness for the development of a fully commercial facility is gaining importance due to the ambitious goal of recycling all plastics by the end of 2030. Household packaging flows are usually of worse quality and lower recycling efficiency compared to industrial and commercial packaging flows, and thus require particular attention [18].

Currently, when there is a constant effort to increase the rate of plastics recycling, the “low-hanging fruit” of clean one-stream plastic waste has already been picked. To be able to meet the ambitious European recycling goals, it is necessary to consider also the flows of plastic waste hat have been considered “problematic” until recently and have been sent to incinerators. One of such flows is fraction obtained from sorting mixed post-consumer packaging waste using the float-sink method. It is a very complex flow in terms of its composition. It also contains a significant quantity of PVC, which is considered harmful to further mechanical recycling of any mixed plastic waste. For this purpose, The Design from Recycling strategy was used for successful development of a new product with this material called Greentile. This material was successfully produced and turned out to be a useful construction material for pitched green roofs [19].

The recycling of plastic waste is of fundamental importance for reducing the deterioration of the environment and ensuring the future security of resources. The quantity of recycled plastic waste grows every year, reaching 83 % in 2014. However, only 26 % and 4 % of the recycled plastic waste is processed using mechanical recycling and feedstock recycling, while 70 % is processed by through energy recovery (incinerating). Therefore, it is necessary to increase the volume of mechanical and raw material recycling. Plastic waste that cannot be processed by mechanical recycling can be converted to oils and gases by pyrolysis. Nevertheless, polyvinyl chloride (PVC) and polyethylene terephthalate (PET) produce corrosive gases and sublimating substances, which leads to the deterioration of quality of pyrolysis products and damage to the waste processing equipment. In addition to catalytic pyrolysis PET with the use of Ca-based catalysts, the method of PVC dehydrochlorination and dichlorination was developed [20].

Increasing the rate of plastics recycling is of crucial importance for solving plastics pollution and reduction of fossil fuel consumption. However, the problem of technologically and economically feasible methods for recycling post-consumer plastic fractions still remains. Profitable value chains for recycling of mixed films and container-like plastics are nearly not implemented today, which is in sharp contrast to the recycling of relatively pure fractions, such as polyethylene terephthalate and high-density polyethylene bottles [21].

Advanced recycling of plastic waste through pyrolysis and subsequent steam cracking of pyrolysis oils can partially close the cycle of petrochemical plastics production and current end-of-life waste management (i.e. down cycling, incinerating, landfilling). However, the biggest obstacle is the complex composition of actual plastic waste and its contamination by numerous additives and residues. As a result, it is necessary to significantly improve the quality of pyrolysis products compared to fossil feedstock using universally applicable methods of refining and decontamination. These methods range from pre-treatment of waste in order to reduce the halogen and additives content through in-situ methods and practices applied during pyrolysis to post-treatment in order to refine the obtained pyrolysis oils using hydrotreating, filtration, or adsorption. By integration into the petrochemical cluster, it is possible to produce high-quality petrochemical material from plastic waste, which, when combined with electrification, could lead to the reduction of CO2 emissions by >90 % compared to incineration, which is currently the most widely used method of waste disposal [22].

The increasing scarcity of resources and growing environmental awareness require a higher rate of plastic waste recycling. The most common methods include mechanical recycling, thermal recycling, and chemical recycling, which is also referred to as feedstock recycling. From these three techniques, chemical recycling is the only method that enables the production of new materials with the quality corresponding to the quality of conventional primary material. However, this technique is applicable to suitable polymers only, such as polystyrene, which can be depolymerised at higher temperatures. For an efficient industrial use, a continuous process is required [23].

The issue of waste remains linked to the development of local communities. The volume of waste stored in landfills affects the quantity of leachate, which results in higher emissions and reduced capacity of the landfill. The main task of waste management is thus to choose the most cost-effective method to minimize the quantity of leachate and emissions and increase the capacity of the landfill, which will lead to the extension of the landfill useful life [24].

Due to the scarcity of raw materials for production of plastics and considering the pollution of the environment it causes, plastic waste recycling is of great importance. Plastics are being increasingly used due to their properties, which have enabled sustainable development of the plastics industry. Currently, a wide range of products are made of plastics, including bottles, panels, sheets, pipes, moulded planks, or structural profiles. Despite these positive properties, developers face frequent resistance in regaining and reprocessing of plastics for using resources and waste depletion [25].

Given the worldwide growing production of plastic products, the technology of waste recycling has been gaining importance in recent years in terms of efficient use of resources and energy savings. One of the advantages of feedstock recycling is that it allows gathering high concentration of monomers that can be reused as crude fuel. Feedstock recycling also includes methods that use the generated gas and residues. Saito et al. [26] identified an increase in the number of technical problems associated with plastics recycling resulting from the growing complexity of the composition of industrial and household waste. On the other hand, it was found that other problems related to feedstock recycling are rooted in political and social systems, although the results varied in the analysed countries.

The ubiquitous use of plastics is also determined by their low price and properties; however, these properties directly challenge the systems of waste management for plastics recycling. Some post-consumer recycling problems are nearly 50 years old, but a large volume of end-of-life plastics are still end up in landfills or other landfilling facilities. With the growing concerns about plastic waste, especially ocean plastics, there is a need to innovate and find alternative strategies to economically convert the plastic waste into a finished product (products) that support its applicability in circular economy. Although there has been identified a wide range of technical strategies for plastics recycling through mechanical and chemical recycling, the commercial use of these strategies is in general constrained either by efficiency, including the large differences in the key indicators, or by economy, where the effectiveness of the product might equal to the effectiveness of virgin materials but the recycling process is costly. Successful treatment of post-consumer plastic waste through recycling will probably depend on economic incentives and government regulations [27].

The global production of plastics from non-renewable fossil resources has grown more than 20-fold since 1964. Although more than eight billion tons of plastics have been produced so far, only a small portion is being recollected for recycling nowadays, and large volumes of plastic waste end up in landfills and oceans. Pollution caused by the accumulation of plastic waste in the environment has become a problem of global importance. Synthetic polyesters, such as polyethylene terephthalate (PET) are widely used as food packaging materials, beverage bottles, coatings, and fibres. Recently, it has been found that post-consumer PET can be hydrolysed by microbial enzymes under mild reaction conditions in an aqueous environment. Within plastic circular economy, the resulting monomers can be recovered and reused for the production of PET products or other chemical substances without depletion of fossil resources and damaging the environment. Enzymatic degradation of post-consumer plastics thus represents an innovative, environmentally friendly and sustainable alternative to common recycling processes. By constructing efficient biocatalysts using protein engineering techniques, the biocatalytic recycling of PET can be further improved and developed towards their application in industry [28]. Extensive research on recycling of plastics and other solid wastes been conducted mainly in China and other Asian countries. Based on their findings, it can be concluded that plastics recycling and legislation are still incompatible (Wang et al., 2020). The author state that in these developed countries, mainly electronic products are sorted out, as they are considered to be consumables. However, the authors disagree on determining correct holistic recycling process of plastics, which are considered consumable as well, even more than electronic products. This problem is not limited to Asia; it is a global problem. The authors thus propose to create a joint project that would be binding for all states.

The ever-increasing demand for lithium-ion batteries and their production result in more problems with their disposal. In China, little is known about recycling lithium-ion batteries from consumer electronics, although China is the world leading producer and consumer of this type of batteries. In their research, Gu et al. [29] found that although the respondents are interested and willing to recycle, most of them do not know where the send the used lithium-ion batteries. According to the research, used lithium-ion batteries are not included in the current collection systems, as only few recycling entities deal with their recycling. Furthermore, Gu et al. [29] found that insufficient supply has a significant impact on today´s recycling industry. Based on official statistics, survey results, and the actual performance of recycling plants, it could be roughly estimated that less than 10 % of lithium-ion batteries used in consumer electronics are recycled, with the remaining percentage ending up in landfills or unused.

Bulach et al. [30] found that electro-mobility will play a key role in achieving the set ambitious goals concerning the reduction of greenhouse gas emissions in the transport sector by 42 % in 1990 - 2030. As a result, a significant increase in the sale of electric cars can be expected, and the number of electric cars for recycling will grow accordingly over time. This applies also to recyclable power electronic modules, which are part of all electric cars as an important part of the energy economy. Current recycling methods using car crushers and post-crushing technologies show a high rate of bulk metal recycling, yet they are still associated with high losses in precious and strategic metals, such as gold, silver, platinum, palladium, and tantalum. For this reason, an optimized recycling practice was developed within the project “Recycling of electric vehicles 2020 – key components of power electronics” for recycling electronic modules from electric vehicles, which is applicable even in batch production and which can be implemented using standardized technology. This recycling method is referred to as WEEE (Waste from Electrical and Electronic Equipment) involves dismantling of power electronics from vehicles and its subsequent recycling in an end-of-life electronic equipment recycling facility. This recycling process is economical under current conditions and with the current prices of raw materials, although its costs are significantly higher than recycling using car crushers. The assessment of the life cycle shows basically good results both in the case of using car crushers and WEEE, but the later provides additional benefits thanks to a higher utilization rate and corresponding credits.

The demand for recycled plastics is growing even in the construction industry. At the beginning, research focused only on the possibility of using plastics in the construction industry. The findings showed that by adding plastics, it is not possible to reach the desired hardness and durability of a given product [31]. The results of further research show that the only benefit of adding plastics in concrete and mortar is the reduction of weight, while the hardness and non-combustibility decreased, and the application of plastics thus brings risks rather than benefits [32]. However, the findings of some studies indicate that this material can be used in some developing or smaller economically not independent. As an example, the Philippines can be mentioned, where recycled plastic combined with construction materials enables building a solid shelter, and can be also a sufficient insulator. Thus, even research that did not bring benefits for most of developed countries are helpful in the poorer countries [33].

The rate of utilizing building materials in China is only 5 %, which leads to environmental and economic problems. Researchers from other countries have identified the potential of building information modelling (BIM) in optimizing building material recycling. Zhang and Jia [34] recommend taking other positive measures to solve the problems related to construction waste; if this not happens, other environmental and economic problems will emerge.

With the rapid industrialization and urbanization of China, large volumes of construction waste are produced in the construction sector, which is becoming an increasingly more important problem for local governments that need to ensure sustainable and efficient construction waste management. In general, scientists agree that construction waste recycling is an important means to inhibit the deterioration of the environment in China. Ma and Zhang [35] state that subsidies to construction enterprises are necessary to support construction waste recycling in China; however, compensation to recycling enterprises is not always necessary, as in some cases, if construction enterprises recycle waste, recycling companies will participate in recycling spontaneously, without any subsidies.

Zhang et al. [36] found that a huge amount of construction and demolition waste (CDW) is generated in China. CDW recycling into base materials is a promising method to process this type of waste, with significant environmental and economic benefits. However, this issue has not been adequately addressed yet. Therefore, based on the example of constructing CDW subgrade in Beijing, physical and chemical properties of materials from CDW were analysed. Subsequently, the process of constructing CDW subgrade were presented, and many tests were performed (compaction degree test, observation of settlement, portable falling weight deflectometer test). At the same time, the impact of various thickness of loose paving and cycles of strong vibration on the properties of subgrade was determined. Next, a sorting analysis of CDW particles, a plate load test, and a Beckman beam deflection test were carried out to evaluate the quality of the structure. Based on the results of these tests, technologies of CDW subgrade construction were determined, such as the optimal thickness of loose paving and cycles of strong oscillation. After that, monitoring of post-construction settlement and radar survey for CDW and soil-filled subgrade was conducted to further analyse the applicability of CDW. The results show that recycled CDW aggregate works is applicable, if accompanied by proper sorting and strict construction technologies. Subgrade filled with recycled CDW shows less deformation than soil-filled subgrade. Finally, life cycle assessment (LCA) was performed for two systems of CDW processing with the aim to analyse its benefits for the environment: using recycled material as a base material and direct landfilling. If subgrade is filled with recycled CDW, large volumes of CDW are needed, which may help significantly decrease the impacts of eutrophication and ecotoxicity on the environment.

In many countries, waste management is increasingly more often focused on circular economy, whose aim is a sustainable society with a lower production of waste, fewer landfills, and higher recycling rate. Waste-to-Energy (WtE) plants, which are focused on converting waste into heat and energy, can be beneficial to circular economy in using the kinds of waste that cannot be recycled. Given the different quality of sorting and socio-economic conditions in individual regions, the composition of waste differs in individual regions, and its future development is uncertain. The composition of waste significantly affects the operation of WtE due to the differences in the energy potential [37].

Plastic is a versatile material that has contributed to many innovations of many products and convenience in everyday life. However, the production of plastics is increasing at an alarming rate, along with the production of plastic waste. Improper waste management leads to release of plastics in the environment, with a lot of negative impacts on ecosystems. Incineration of plastic waste produces excessive greenhouse gas emissions, while plastic as material is consumed and cannot be reused as a resource within circular economy. For this reason, the European Union (EU) is taking measures to increase plastic recycling and is introducing higher recycling targets in its revised waste legislation. Its example is followed by Sweden, which prioritizes measures to improve plastic waste management. It can be stated that the most promising and sustainable scenario of future plastic waste management in Sweden includes high recycling targets in accordance with the EU goals and gradual end to plastics incineration as a method of waste disposal [38].

In the world, recycled plastics are often used in the clothing industry. In spite of this, plastic by-products are still significantly affecting the environment. This is most reflected in the pollution of waste water, where the most microplastics and chemicals from fabric dyeing end up [39] Fashion companies are well aware of this fact. Therefore, they have undertaken in the Paris Agreement to achieve zero emissions by 2050. The goal of the research by Shitvanimoghadam et al. [39] was to focus on natural dyes and focus on the technology of waste water treatment to prevent microplastics to get into oceans. According to Cook, Halden [40] 50–80 % of waste gets to oceans by recycling. This was confirmed also by in the case of chemicals used in recycling. The issue of recycled materials was addressed by Jafari [42] whose main research interest was the analysis of demand for recycled plastics in the clothing industry. According to the author, the issue of plastic recycling is essential mainly in terms of its sorting and cleaning, the costs of which remain very high. The author proposed several solutions, based on which it can be concluded that if companies are supported by subsidies to create cleaning lines, and the price at which the cleaned plastics will be sold is capped, it will bring benefits to everyone [42].

The rapid development of the textile and clothing industry leads to the continuous enrichment of material and cultural life of mankind, but is also associated with the lack of resources, pollution to the environment, and environmental imbalance. On the other hand, with the accelerating pace of modernization of fashion trends, the life cycle of clothes is gradually shortened, resulting in a large amount of unused clothes. In order to mitigate the consumption of natural resources, minimize the burden on the environment, building a “recycling society” cannot wait [43].

Increasing pressure on resources and increasing amount of textile waste are making recycling a clear priority for the fashion and clothing industry. However, textile recycling is still limited, and therefore, it is the focus of upcoming EU policies. As the fashion industry is involved in complex value chains, the promotion of textile recycling requires complex understanding of the existing problems [44].

Knowledge of the origin and production of resources is an important issue for the sustainability of the textile industry. Recycled materials are expected to form a significant part of resources that will be used in the future. Textile recycling, especially post-costumer waste) is still in its infancy, and will pose a great challenge in the future. Better understanding of the development in the area of textile recycling is hindered by three basic problems: current classification of textile fibers (natural or artificial) does not support textile recycling; there is no standard definition of textile recycling technologies; lack of clear communication of technological progress (from the side of industry and brands) and the advantages of textile recycling from the side of consumer. This may hinder the much-needed further development of textile recycling. Harmsen et al. [44] conclude that there are good possibilities of recycling for mono-material flows within the cellulose, polyamide, and polyester groups. For blended textiles, the outlook is promising for blends of fibers within one polymer group, while the combination of various polymers can cause problems in recycling.

After the Covid-19 pandemic, ecology started to be discussed much more. The European Union is trying to create new regulations and taxes concerning plastics. The first such regulation was to reduce consumer plastics in the food industry, specifically plastic cups, straws, plates. The gradual introduction of regulations and directives shall lead to using the recycled materials mainly to replace fuels [45]. At this time, there is lack of fuels, and in the current energy crisis, their replacement by plastics could mean a benefit in the form of heating homes. Before the pandemic, this was addressed in more detail by Bac [46]. On the example of Turkey, the author performed an analysis of plastics recycling. Turkey has promised zero emissions by the end of 2025. As the basis, it is necessary to create investments in companies that will be financed by the state. Thanks to this, companies can certify the recycled materials, which will guarantee the necessary quality. If this method proves successful, it can be applied in other countries [46].

The last aspect to sorting and use of recycled materials is the motivation of population. In Finland, people who are involved in the project of sorting were offered financial incentives. The majority of the participants (52 %) agreed that finance would be greater motivation than recycling. Abila and Kantola [47] concluded that it is necessary to establish a recycling policy that would specify these rules and there will be no need for financial investments. Khalid [48] conducted a study on citizens´ motivation in the form of raffles or discounts for sorting. This study included 1153 households. People were awarded virtual tokens that could be exchanged for goods in raffle or discount on some goods. Although this research was beneficial, it was clear that motivating people is not enough. It is necessary to make decisions now, which provide immediate results, not only to think about whether people are able to do it [49]. Plastics and recycled plastics need to be further analyzed in order to fulfill our obligations to the environment.

Growing environmental concerns caused by excessive use of synthetic materials attracted the global attention to sustainable materials along with the approach of circular economy using recycling. Currently, composite materials are being used enormously in various industries, which results in accumulation of plastic waste in the environment. End-of-life processing of plastic composites is necessary because these materials are not easy to dispose of. The recycling methodologies adopted for polymer composites have two major advantages. First, recycling techniques control the consumption of composite plastic waste. Second, the amount energy necessary for recycling composite plastic materials is relatively low compared to common manufacturing techniques. Thermal recycling is most suitable for recycling carbon and glass fibers. Thanks to thermal recycling, the properties of recycled materials correspond to the properties of original materials, and energy consumption is significantly lower than in the case of chemical recycling. Mechanical recycling, however, has a very low consumption energy for recycling composites compared to other recycling processes. It has thus been concluded that the consumption of composite materials in various industries would only be justified if recycling and reuse of composites were paid equal attention to. Recycling of polymer composites also supports circular economy [49].

One of the biggest environmental problems is currently environmental pollution caused by excessive production of waste. One of the ways to partially eliminate this problem are packaging free shops. Rovnak et al. [49] found that packaging free shops should target their marketing on all generations of consumers and focus on finding suitable ways to increase the level of interest of all age groups.

To make the world more sustainable, participation and cooperation of all market actors (the state, companies, and consumers) is necessary. The new economic model, circular economy, is a concept to achieve sustainability goals. Circular economy and its main principles are based on the idea that all material and product flows can be (after their use) returned to the production cycle so that they become new resources for production and provision of services. In an ideal case, no waste would be generated any more. Packaging free shops are a good example of implementing the principles of circular economy into business practice [50].

Although packaging free shops are popular, disposable packaging still remains an integral part of self-service supermarkets. Sattlegger [51] used ethnographic analysis to prove that food packaging is essential for the functioning of supermarkets. This is in contradiction with the engineering or marketing perspective, which often do not take into account the practical requirements and habitual idiosyncrasies of everyday work processes. Packaging, established as a code of practice, guides everyday food handling in three basic ways. First, packaging is a multifunctional means for presenting the goods to customers. Second, packaging is an indicator and converter for evaluating the quantity and quality of products in the internal logistics of supermarkets. Third, packaging enables control and reproduction of representative characteristics of supermarkets, such as freshness and fullness. As a result, and in order to be successful, strategies for reducing the volume of packaging waste need to better consider the diversity of functions packaging has in work processes. Planners of innovation processes need to consider professional knowledge of workers, the history of packaging, situational distribution of activities, and cultural frameworks of supermarkets.

3 Data and methods

The main data source will be data from a questionnaire survey created using Google Forms. The questionnaire is anonymous and will be distributed on the Facebook profile of company Meta and will also be sent to the author´s friends and acquaintances. The questionnaire contains ten questions (1 open-ended question, 2 semi-closed questions, and 7 closed questions). In some questions, it is possible to state own view or experience. The data will be evaluated for 21 days, with the questionnaire being distributed in April 2022. The responses will be evaluated by grouping the resulting data in two groups. The first group will contain responses to the questions related to legislation of plastics sorting. The second group will contain responses to the questions related to personal motivation, willingness to sort out and use recycled materials. The data will be processed in Excel by Microsoft. In the program, three tables will be created, where two of them will evaluate the responses of respondents and the results will be presented in percentage. The third table will evaluate the responses to the open-ended questions. In some questions, it is possible to obtain more specific answers that will be included in the Results chapter. After data processing, pie graphs will be created according to the groups of responses. All results will then be averaged to be able to answer the research questions. Another data source will be the website of the Czech Statistical Office (www.czso.cz). Based on this data source, another table will be created in Excel, which will process the data on sorting out plastics in the Czech Republic for the last ten years, i.e., the period 2010-2020. Unfortunately, the CSO creates only statistics concerning the return rate of municipal waste as a whole, not according to the individual types of waste. Based on these data, the comparison of these evaluations will be carried out. Both documents will be attached to this paper as appendices.

First, there will be used the results that enable direct evaluation of the questionnaire survey. The data will be entered in the created tables in Excel according to the given groups. In the next list, tables with the sum of all data according to the given group will be created. Using the formula for calculating the arithmetic means, the data will be evaluated and presented in percentage. Based on the data, a pie chart will be created, which would clearly show the results that were achieved on the basis of the respondents´ reactions.

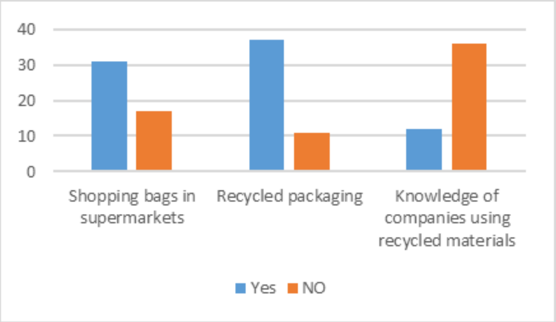
$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad (1)$$

In the case of the second group, a table will be created, where the data on sorting out plastic waste according to the Czech Statistical Office will be entered. These data will be presented in tons. Based on the table, a column graph will be created, which shows the development of plastics consumption in the Czech Republic in the monitored period.

4 Results

Graphs 1 and 2 clearly show that two thirds of the respondents sort out plastics and are willing to make more efforts to return the recycled plastics in the circular economy, although nearly one third of them do not know what happens with plastics after being thrown in the containers. It followed from the responses that people are aware of the existence of recycled materials and even prefer e.g. shopping bags from recycled materials in the shopping markets. The most engaged ones even know which companies sell consumer goods made of recycled materials (8 out of 48 respondents). The most frequently mentioned company was Mattoni and its recycled PET bottles. Other examples included Kofola, EKO-KOM, Puruplast, Adidas.

Graph 1: Respondents´ preferences

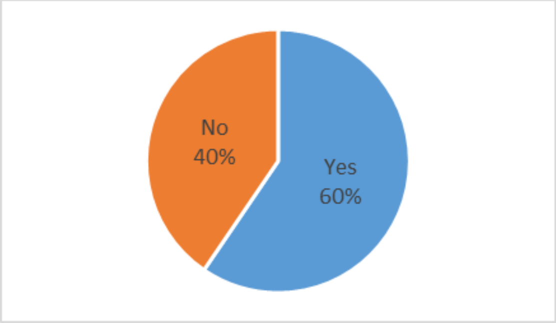


Source: Authors.

In the open-ended question, the respondents could express their views to the issue of plastics and their recycling. It can be said that all responses are connected to each other. Overall, these answers correspond with the research conducted by various scholars [14]. There is a typical response on tat it is surprising how much plastic waste can be found in nature, including micro pieces that are difficult to remove. This response is followed by another one where the respondent states that education concerning sorting is still not adequately taught and promoted. There are also responses indicating more accurate and thorough sorting. The respondents who deal with sorting and recycling in more detail provided more professional responses and opinions, such as to choose a more ecological method of cleaning and production of plastics intended for recycling, or not to direct such large quantities of plastics to incinerators. The respondents pointed to the quality of plastic products that can be repeatedly used. As an example, the respondents mentioned a 60-year-old basin that seems to be "undestroyable" compared to some newer ones. Another very common phenomenon pointed out by the respondents is that even if a company has bins for recycling on its premises, the cleaning companies often mix the sorted kinds of waste with others.

The question concerning returning and possible recycling of PET plastics shows that 44 respondents agree with returning. The biggest obstacles can be seen in the points where returnable bottles will returned. This is confirmed on the case of Slovakia where PET bottles returning has been introduced but not all shops buy them, which is demotivating for many people. The remaining four respondents state that the reason why they do not agree with PET returning is the poor storability of PET bottles. One of the respondents mentioned that washing these bottles is less eco-friendly than making a new bottle.

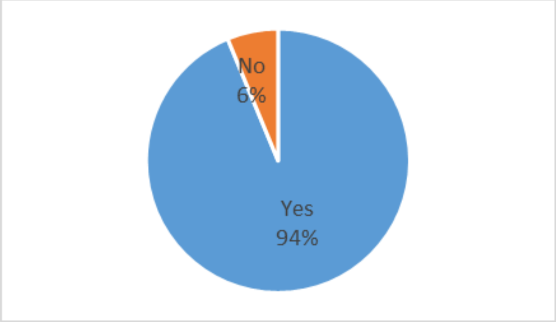
Graph 2: Graph concerning the motivation



Source: Authors.

The data shown in Graph 3 concern the set of questions related to legislation and clearly show that people call for necessary taxation. In the first question, the results show that 43 respondents want companies dealing with recycling or sorting to have established taxes that would motivate them to sort out in accordance with the legislation. The follow-up question was whether companies should use recycled material in its products, and the result was a clear yes. All but one respondent agreed that the government should invest more in recycling.

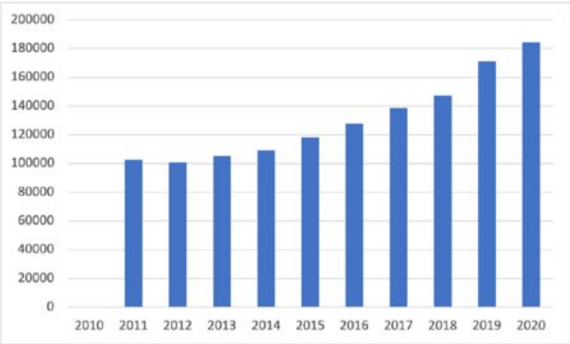
Graph 3: Graph showing the responses on legislation



Source: Authors.

The data from the Czech Statistical Office presented in Graph 4 clearly show that the volume of plastics in municipal waste is growing every year. The only decrease was recorded in 2012. In the years 2011-2015, the volume of plastic waste increased by 3000 tons on average every year. Between 2016 and 2017, the production of plastic waste increased by 9000 tons on average. In 2019, the highest increase was recorded by nearly 24000 tons. In the year 2020, the increase was lower, achieving 13000 tons.

Graph 4: Volume of plastics in municipal waste in 2010-2020 (in tons)



Source: Authors based on data from ČSZO (2022).

5 Discussion

The data obtained enable answering the research questions:

Is it possible to achieve using recycled material on regular basis if legislation is the motivating factor? The state cannot ignore the trend of increasing volume of plastics in municipal waste. The data obtained through the questionnaire clearly show that people would welcome taxes that would promote sorting and mainly using recycled materials in products. Of course, this is not an opinion everybody would agree with. A smaller part of the respondents has a rather negative attitude towards this suggestion, as they do not believe that taxes or recycled materials would be the best solution, as there always be somebody who would not follow the rules.

How to motivate people in the Czech Republic to decide for the more costly but more ecological alternative over the cheaper but non-ecological one? A surprising finding was that people are willing to pay more for ecological products without being motivated by the state or companies. It can thus be concluded that the Czechs are interested in recycling out of their own convictions rather than being forced by legislation; however, almost a third is not aware of how plastics are treated after being sorted out. Returnable PET bottles are considered to be a good idea; however, the respondents expect that without clearly set rules, it will not work. Therefore, none of the respondents uses returnable PET bottles. This can be used for example on the website košík.cz, where it is possible to return the used bottle when ordering. This is, however, conditioned by another purchase, which is what the respondents do not agree with. For now, they consider this to be certain discomfort they are not willing to accept now. It is now becoming known that there are companies that are already using recycled materials to make their products.

Basically, both research questions can be considered answered, because the basis for achieving the goals is to prepare legislation that would motivate companies and persuade people that it is meaningful and important. The Czechs are prepared to fulfil their obligations to nature. The Czech Statistical Office should also consider more detailed statistics concerning plastics recycling because the existing data are too general and have been monitored for ten years only.

The need for creating legislation and taxes concerning recycling was also addressed [52] who state that legislation on plastics recycling must be uniform globally. If only some states will comply with it, the effect of recycling will be minimal, as companies will use the cheaper alternative of plastics disposal in a state where stricter environmental regulations are not introduced.

6 Conclusion

The goal of the paper was to determine the optimal conditions for households and companies in the Czech Republic to use recycled plastics so that the goal was achieved with the smallest possible capital and environmental burden. The responses from the questionnaire survey showed that the respondents are well informed about the issue and should thus be aware of the fact that the more expensive alternative is important for the conservation of the environment. They are prepared to accept the future capital or tax burden if for a good cause. The goal was thus achieved.

However, it turned out not to be true for all respondents but a solution was found. The government of the Czech Republic should focus on raising the public awareness concerning plastics recycling and using the recycled material. For this purpose, the Czech Statistical Office should monitor more detailed data on plastic waste so that the information for the population is more accurate and targeted. Furthermore, the government should establish effective taxes that would correspond with the goal of the smallest environmental burden possible. Nevertheless, this problem should not be solved at the level of individual countries but globally.

The limitation of this paper is the volume of the data, since the questionnaire was not distributed to many respondents. Another limitation is also the way of distributing the questionnaires where the identity of the respondent cannot be verified. Further research could include a higher number and range of respondents and more comprehensive research could be conducted.

The benefit of this paper is a certain view to plastics recycling expressed by a small number of people who are able to influence other people in their surroundings. The fact that they are interested in this issue and that they are willing to address it enables us to fulfil our obligations to nature without any financial costs of education from the side of the state.

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Primary Paper Section: D

Secondary Paper Section: DM, DN