POLITECNICO DI TORINO

Corso di Laurea Magistrale in Ingegneria Gestionale

Management of material lifecycle information to support Circular Economy

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Anno accademico 2021/2022

ACKNOWLEDGEMENTS

Before proceeding with the discussion, I would like to dedicate a few lines to all those who have been close to me on this path of personal and professional growth.

I thank Lucilla and Eros, to their constant support and teachings without which I would not be who I am today. Without you, none of this would have been possible.

I thank Simone, who has always been a point of reference and further stimulus for the results he has been able to achieve that have spurred me to give more.

I thank Beatrice, a light that gave me strength and accompanied me along the way.

I thank my friends, for being my accomplices, each in their own way, in this intense and exciting journey, for better or worse.

I thank Giulia Bruno and Luigi Panza who made me passionate about the topic covered in the thesis without which I would not have understood the importance of some of the elements analyzed.

Finally, I would like to dedicate this small achievement to myself, may it be the beginning of a long and brilliant professional career.

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ABSTRACT

Current concern about the risks and potential problems to the environment associated with people lifestyles and even more with the sourcing and production of materials has brought to light the need to pursue more natural and sustainable models for managing resources and waste. For this reason, the Circular Economy addresses the challenges for sustainable production and utilization of planet resources.

In particular, the recovery of used materials is a major challenge to be overcome. Although significant improvements have been made, there is still room for further advances. One of the main issues is the availability of frequent information exchanges from all actors in the supply chain, in order to work through all stages of the material lifecycle.

Therefore, this work focuses on the study of a framework to manage such information through the use of a digital tool called Material Passport. The objective of the work is to illustrate the framework and apply it in a case study of plastic packaging.

1. CIRCULAR ECONOMY

1.1 INTRODUCTION

Continued economic growth has steeply increased the demand for resources over the last decades. The increase in the exploration of ever new resources and the decrease in mineral deposits have increased the pressure on resources. Without a change in this sense, the situation will turn into the disappearance of more than twenty critical materials in the next fifty years. Without neglecting the fact that this will lead to further scarcity of resources, favoring economic macro-powers to those that are growing. This is because the economy will rely more and more on resources. A lack of these materials will make the economic system more vulnerable. To avoid this involution, the reuse of certain materials is essential, transforming the current system into a circular system.

However, too few tools have been created to meet this need, in order to operate on a large scale. This leap forward is difficult to make because it requires trust, costs and very often reduces the quality and availability of information. Only with the exchange of information will companies be able to make up for the scarcity that has been created in recent years, which is linked to growth, return on capital and risk management.

1.2 PROBLEM DEFINITION

The demand for different materials has increased significantly in recent years. The Sustainable Europe Research Institute (SERI) has assumed that in the next world scenario the extraction of finished materials and minerals will grow from 19 billion tons in 1980 to 53.7 billion tons. There is talk of growth that exceeds 280% in just 5 decades. It is estimated that in the same period of time the consumption and therefore the demand for food will increase by 70%. At present, with the non-reuse of these resources, two planets would be needed to make up for this shortage and meet the demand. We are talking about a historical period that is not so distant and that will impact our life and that of our children in the future. The pressure on resources has increased, due to a significant waste generated in the production process without neglecting the fact that fewer and fewer mineral deposits are discovered, thus increasing exploration costs and the energy used to find them.

Without an answer to these problems in the next decades we will run into a shortage of 22 critical materials, counting that these are not distributed equally among the different states, this problem will show itself in a struggle to possess them, causing even more disparity between different states. economic powers. In 2010, in fact, the European Union highlighted the 35 metals that could be critical to the economy in the coming years and which would therefore have considerable importance from an economic point of view and beyond (McKinsey Global Institute).

The world economy is very dependent on the various materials that make up the planet, in particular Europe given the lack of sites where the various elements can be mined. The largest deposit of elements resides in the materials already built such as houses, infrastructures, televisions, computers, etc, especially in countries such as Italy. To be able to support the growing demand for materials, it will be increasingly necessary to reuse and recycle materials. In a study shown by the United Nations Environment Program it showed that less than 1% of Rare Earth Elements (REEs) are recycled. This low level of recycling represents a wasted opportunity. One of the biggest barriers is the lack of communication and information between the parties.

1.3 RESOURCE SCARCITY

The resources we use are defined as “natural assets deliberately extracted and modified by human activity for their utility to create economic value. They can be measured both in physical units (such as tons, joules or area), and in monetary terms expressing their economic value "(UNEP, 2011: 2). "Scarcity is the concept of finite resources in a world of infinite needs and wants" (PBL, 2011: 18).

A distinction can be made between the various definitions of scarcity: political, physical and economic.

The political scarcity derives from the fact that not all raw materials are distributed equally in countries, there are countries that import, others that export and still others hybrids. Physical scarcity is related to the presence or absence of this in our ecosystem, however this remains an unknown because it is not possible to estimate the exact amount still present on the planet. Still the only way we have to get an idea is by having the number of physical resources present on our planet and the consumption we make of them to see how long this resource will be available. Economic scarcity, on the other hand, is measured as a function of the market and demand and asks whether at that historical moment there are resources available to satisfy the required quantity.

Resources can also be classified as finite as oil, minerals and materials, which are therefore not renewable once used and renewable resources such as water, solar heat and some foods that we consume every day on the table. However, there are also problems here that could arise over time. One of these could be an insufficient production of these resources, or a lack of information, problems of transport and distribution to the final customer.

The renewable resources we know now are continuously growing but at present they do not seem to keep pace with the continuous increase of the population, quadrupled over the last century and the rapid increase in the use of resources which in the same period of time has increased the demand of about 2000%.

Unfortunately, to meet this demand there would be a need for continuous access to resources that cannot be allowed for a long time, in Europe alone, a continent all in all close to environmental issues, the use of only 11% consists of renewable resources. Too little for non-renewable resources to run out shortly thereafter.

There is no waste only in demand, even the current industrial system produces waste in the various steps that bring the resource to the end user.

About 21 billion tons are not physically incorporated into production, skipping the first process, just think of by-catches from fishing for example.

Furthermore, many materials lose their function once they are finished being used. In 2010 alone, about 65 billion tons entered the economy.

The same year, in Europe alone, 40% of these materials are recycled, reused or have a second life after their main use. We are talking about more than 40 billion tons wasted after the life cycle (EPRS, European Parliamentary Research Service). This is a sobering figure because it reflects the failure to attempt to close a cycle that has been linear in past centuries.

This situation is analyzed in Table 1, which tells how minerals and metals are slowly ending their cycle. Within 10 to 50 years the reserves of 22 metals and minerals will run out, becoming physically scarce.

Table 1: Metals and minerals availability. Source: Diederen, 2010.

Name	Year left	Name	Year left
Antimony	11	Copper	27
Silver	12	Thallium	28
Strontium	12	Manganese	29
Zinc	14	Mercury	29
Tin	15	Nickel	31
Arsenic	17	Niobium	32
Gold	17	Bismuth	35
Lead	18	Rhenium	35
Barium	20	Tungsten	37
Cadmium	20	Yttrium	40
Zirconium	21	Iron	46

Over the next 20 years the demand for some of these metals, such as steel, is expected to grow by about 80%, given the increase of three billion consumers in the middle class, just think of the new purchases of cars, for example, or the need for new infrastructure, especially in developing countries.

The current economy exploits materials at almost zero cost, however, going to exploit the environment in which we live, deteriorating it. This is a fact that can be seen in the table above but even more so in most of the products we eat every day such as meat and fish. The latter have been extensively studied by The Food and Agricultural Organization (FAO, 2010) estimated that 50% are fully exploited. Or how deforestation to have sufficient timber affects rainfall and therefore crops. It is now obvious how the growing demand brings serious damage to the earth's environment without the possibility of having a second chance, making us even more vulnerable.

It is estimated that by 2050 the demand for food and fiber will increase by 70%, constantly impacting an already degraded sector.

Over the last few years there has been a trend in many materials and therefore their price is correlated. This correlation has increased over the last few years, with covid-19 first and subsequently with the tensions between Ukraine and Russia, leading to poverty only from 2000 to now about 44 million people (World Bank, 2011).

1.3.1 Consequences of resource scarcity

The consequences of the scarcity of materials can be analyzed in three different ways:

1. *Economic perspective*, short-term costs and long-term economic sustainability.

2. *Social perspective*. Extraction and use of resources affect people's health, employment, and cultural heritage. Moreover, the equity aspect, like equal sharing of the profits, is part of this perspective.

3. Environmental perspective. The exploitation and use of resources affect the rate of extraction and depletion of renewable and non-renewable resource stocks and the extent of harvest and the reproductive capacity and natural productivity of renewable resources.

World's economies are directly and indirectly based on the use of material resources. Europe, in particular, uses resources such as fuel, metals and minerals but also food, water and ecosystems.

Studies have not yet been carried out that verify the lack that the resources mentioned above could impact worldwide. The focus will be on non-renewable resources because a materials passport is mainly provided for these types of resources.

The European Union is almost completely self-sufficient in food supply and is one of the largest exporters of agricultural products. The problem, however, is that after 1000 years of mining, Europe has almost run out of its primary metal resources. This has led to interest in less developed countries, transferring the problem to another part of the world. The European Union is the region of the world with the largest net imports, depending on some countries for imports of REE, cobalt, antimony and platinum, 83% of iron is taken from other countries. The high-tech industry relies heavily on these materials and when China cut its export quota in 2010, the high-tech industry was faced with a problem of available raw materials.

The shortage of these critical materials, which have specific properties essential to emerging technologies such as solar cells, wind turbines and fuel cells, can hinder the spread of these technologies and prevent other innovations.

1.4 THE CIRCULAR ECONOMY

After analyzing the catastrophic scenario that we can face by continuing along the path we have taken, it is clear that in order to avoid the problems of economic, political and physical resources, another path is needed. If now the idea of economy followed a linear pattern, for some years now Europe, the United States, Japan and China have been trying to bring society into the circular economy more than other states.

In our current economy, we take materials from the Earth, make products from them, and eventually throw them away as waste, the process is linear. In a circular economy, by contrast, we stop waste being produced in the first place.

"With our size comes responsibility. The way fashion is consumed and produced today is not sustainable. We have to transform the industry we are in. Our ambition is to transform from a linear model to become circular" (Pascal Brun, Head of Sustainability at H&M).

My father never liked luxurious and expensive cars, so when one day the engine of his beloved Ford stopped working after 10 years he decided to buy a brand new one to the amazement of his neighbor who said: "I'm happy that you have finally got a new car". This concept, like many others in our society, is even too well rooted to associate the "new" as the "beautiful". But is it really so?

Everything that is waste in nature becomes a resource for others, in a sort of infinite cycle. This is not the case for modern man who has learned to use a product and then subsequently throw it away, in a process that is defined as linear.

This problem can be solved by closing the circle, minimizing the risk and reducing waste. The final products will be the result of different objects, a broken product can have a second life and gas emissions will be reduced by at least 70% increasing the workforce by 4%.

All this expressed in two words: circular economy. The circular economy model includes those elements that are reused and extend the life of the same and those old elements transformed into new ones by recycling the materials. The people in this system are central to this model. There are three types of industrial economics: linear, performance and circular.

The linear economy transforms natural resources into material that can be sold, leaving the owner the ability to reuse it, sell it or throw it away. This process is certainly the least demanding and is guided by the motto: “bigger-better-faster-safer”. Businesses make money from this method by selling high volumes of new and new merchandise at low prices.

The performance economy takes a small step forward and is very suitable for products through leasing or rent. In this case the owner takes on any risks and hidden costs by earning from the possession of the asset.

The circular economy, on the other hand, reprocesses materials, reserving energy, resource consumption and waste. The goal is to maximize the value of each product reused in each process, creating new jobs here too.

In recent years, thanks to digitalization and with more and more e-commerce, various possibilities have emerged where you can buy second-hand products such as Ebay, Togoodtogo, Vinted and Swappie. This allows everyone to have an accessible market on two extremes, buying and selling, encouraging any person to take an interest in the issue. This concept is not trivial because it allows everyone to be able to make a big contribution to the cause by buying products that have already had a life cycle and extending it. A bit like it happened a few years ago in the various markets of the country but radically larger scales because it is capable of having a huge market, only EBay has 157 million users, or Facebook which has now exceeded one billion.

To have a circular economy we will have to use energy and funding on various fronts. Starting from research and development, social and commercial. By designing new products ready to be reused and standardizing components. However, investments in communication and information strategies are also important to bring the concept to users and consumers but also to companies. The government could promote initiatives aimed at the reuse of material, encouraging reuse and penalizing waste.

The linear model leads to a number of problems:

- Raw materials are extracted at a faster rate than they can be replenished.
- Once the products are no longer used, they are discarded, incinerated or taken to landfills
- Sometimes, unsafe products are disposed of in an unethical and incorrect way, releasing them into the air, soil or water
- The production and transportation of products brings pollution that could be used in another way

As we will see in previous chapters, there are some resources that are running out given the huge number of people who use them. These problems are significantly reduced by the adoption and transition to the circular economy, where products can be reused and exchanged between people, reducing the environmental impact.

For example, people can trade products and own them together to get access to products they don't need in everyday life. Renting and leasing products creates greater flexibility and stability by increasing the likelihood that a product or material will have multiple owners over its life. Companies are increasingly offering product-as-a-service solutions where access to features, maintenance, repairs and upgrades are included in a customer-purchased service. When products last longer, more people are engaged in repair and maintenance activities than in the linear economy.

1.4.1 From an open-ended economy to a circular economy

At this time, waste is created at each part of the production process and then discharged into the external environment that we all know, this waste also includes various elements that can affect the planet in the long term, such as carbon dioxide. This is explained very well in the First Law of Thermodynamics which explains how matter and energy can be transformed but not created or destroyed, which means that waste cannot be made to disappear.

This is basically the difference between the various tools we have at our disposal, in the case of the linear economy a finished product is thrown away, in the second case it restarts its life path considering the laws that govern the universe.

The circular economy is characterized by a series of rules and principles that are not present in the linear economy to which we have been accustomed in recent years.

- Principle 1: The goal is to make resources more efficient and to do so the cycle must be as small as possible.

- Principle 2: Life cycles have neither a beginning nor an end.
- Principle 3: Continuing ownership of a product is cost-effective as it saves twice as much transaction costs.
- Principle 4: The speed of a cycle is very important, the efficiency of the use of stock in the circular economy increases as the flow rate decreases.

These principles and the functioning of the life cycle of a product are analyzed in figure 1, it can be seen how by making the cycle faster and consequently the recovery of a product, the resource is recovered before allowing the system to re-enter it in families or companies without having to extract new resources.

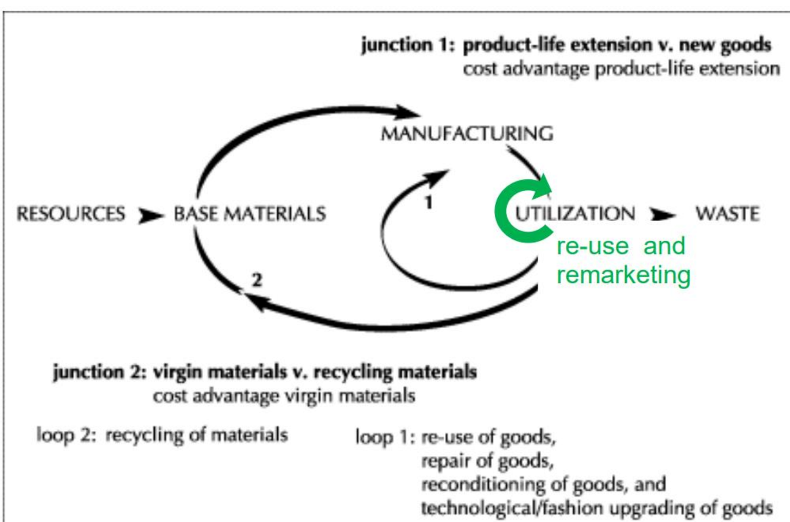

Figure 1: The main loops of a circular economy, Stahel W.R. and Reday, (1976/1981)

As we can see the circular economy is about the sufficiency and efficiency of materials and resources.

Stahel in 1985 showed that in the circular economy there are several ways to increase the efficiency of materials. One of these is technical innovation that from systems solutions rather than product innovations, an example may be air transport systems. A second possibility is to extend the life of a product, extending its life cycle and reuse.

A third possibility is the intensive use of goods to increase the efficiency of materials, an example is the sharing of use as in public transport or the use of the same product such as rental cars. These are options that imply a new relationship with the products we use that were discussed and interpreted already in the 90s, but only now they are finally meeting supply and demand, just think of the initiatives of car sharing, bikes, scooters and more.

In Figure 1 it can be seen that there are two different systems of resource efficiency in the circular economy: Cycle 1 represents the extension of the life of a product while cycle 2 concerns the efficiency of products in recycling. In cycle 1 they concern product specifications and their extension over time, in cycle 2 they are material specifications, be it plastic, paper or ceramic. The latter are chemical and physical recycling processes that end with production or crushing processes in order to be reused.

1.5 THE PRINCIPLES OF THE CIRCULAR ECONOMY

One of the fundamental principles of the circular economy is that resources are gold. At the heart of the circular economy is the intention to reinvent the waste process, this is based on the idea that there is no waste. To achieve this, the products are designed to last as long as possible. Ultimately, these product cycles differentiate the circular economy process apart from disposal and recycling, where large amounts of energy and manpower are lost to recover materials. The ultimate goal is to preserve and enhance natural capital by controlling limited stocks and balancing the flows of renewable resources.

Another important element for the circular economy is to distinguish between technical and biological cycles. Consumption occurs only in the seconds, where the bio-based materials are designed to complete a cycle, which begins with the insertion into the system, such as food, and then passes through processes such as composting or digestion. These cycles have the ability to regenerate living systems that provide resources for the economy, such as seas and oceans and soil. Unlike this, technical cycles do not have the same treatment as washing machines, mobile phones or motherboards and therefore must be recovered and restored through strategies such as reuse and recycling. Ultimately, one of the objectives of the circular economy is to optimize resource yields by circulating materials and products, both in the biological and technical cycle.

The last principle concerns the fact that the energy used to power this cycle must necessarily be renewable and limit its use as much as possible, with the aim of reducing dependence on resources.

There is a rule that allows you to preserve the environmental balance, the 3S rule: reduce, reuse, and recycle. In practice, everything that is used returns to nature in an ecological and cyclical way. As regards the circular economy, we can think of the 7R rule:

- **Redesign:** Redesigning products so that their process consumes less and uses more recycled materials
- **Reduce**: Rethink your lifestyle by having habits that can be more sustainable and reduce waste and the impact on the environment.
- **Reuse**: Products must be reused to extend their life
- **Repair**: Repairing a product allows less waste of raw materials, this is less expensive and reduces the use of energy and waste
- **Renovate**: Renovate and improve old appliances so they can be reused
- **Recycle**: Reuse as much as possible to produce new products starting from old materials.
- **Recover**: Recover old products to give them completely new functions, such as turning a plastic bottle into a jar

1.6 BENEFITS OF THE CIRCULAR ECONOMY MODEL

Since the increase in industrial production, man has always followed a linear economy model that is based on the use of a material until its end. Raw materials are transformed into finished products, sold and subsequently wasted.

To counter this model, the circular economy is based on the recycling of materials to improve product performance and combat the volatility that climate change could bring to businesses. It presents significant economic advantages to companies such as:

Less greenhouse gas emissions

It protects the environment, reducing emissions, minimizing the consumption of natural resources and reducing waste generation.

The fight against the overexploitation of resources and minerals plays an important role. The circular economy has the ability to significantly reduce greenhouse gas emissions and the use of raw materials, optimize productivity deriving from agriculture and decrease the negative externalities brought about by the linear model. For this theme, the circular economy can be useful:

- Because it uses renewable energy that in the long term is less polluting than fossil fuels.
- Thanks to reusing, less materials and production processes are needed to provide good and functional products.
- Since the preferred choices will be energy-efficient and non-toxic materials and manufacturing and recycling processes will be selected.

As a matter of fact, an Ellen MacArthur Foundation study found out that a circular economy development path could halve carbon dioxide emissions by 2030, relative to 2018 levels.

Healthy and resilient soils

One of the principles of the circular economy is that some important nutrients are returned to the soil through composting processes. In this way, as the materials are returned to the soil, the latter becomes healthier and more resistant, creating greater balance and fewer products to dispose of. This seems to be a minor problem, in reality it hides many hidden costs that the circular economy could solve, such as increasing the use of fertilizer for the soil, land degradation costs, loss of biodiversity and unique territories. In a study by the Ellen MacArthur Foundation it emerged that an economy model described above that works in European food systems has the potential to reduce the use of artificial fertilizers by 80% and thus contribute to the natural balance of soils.

Fewer negative externalities

One of the circular economy's principles is that negative externalities such as land use, water and air pollution are better used, as well as the emission of toxic substances and climate change.

Increased potential for economic growth

It benefits the local economy by encouraging production models based on the reuse of nearby waste as raw material. It is important to note that this new model also has advantages from an economic point of view, added to a cheaper production to reach products and materials in a more functional and easier to reassemble and use.

More resources saved

We are in a historical period in which a population increase is now inexorable and uncontrollable, especially in the middle class, for this reason making better use of resources is fundamental. A circular economy leads to a lower need for materials, focusing on the life cycle of materials. From an environmental point of view, it decreases or eliminates the increasing pollution and the extraction of always new materials. According to the Ellen MacArthur Foundation it will lead to more than 70% material saved. On the environmental side, it also avoids bigger pollution that extracting new materials would represent.

Employment growth

It drives employment growth, simulating the development of a new, more innovative and competitive industrial model. A not negligible aspect derives from the fact that a new market segment would certainly bring new investments and therefore new jobs and topics for study and debate in a completely new market. According to the "world economic forum", this new inclusion in the global market will lead to greater local employment in entry-level and semi-skilled jobs.

Ellen MacArthur Foundation conducted a study on the changes in employment growth in the transition to the circular economy. These jobs will be in particular:

- Designers and engineers in drafting recycling and repair practices
- An increase in the volume of consumption with lower prices
- A new figure capable of analyzing the data held by companies for the reuse of materials

- A professional capable of drafting the Material Passport and able to develop it for his own company
- Increase of new business models based on innovation processes
- Reverse logistics companies that support the reintroduction of products into the system at the end of their life
- Marketing of products that facilitate a longer life or greater use of the products used
- Reconditioning of parts and components and reuse of products offering specialist knowledge

New profit opportunities

Moving towards a different and circular economy model means reducing the number of materials used. Instead, more recycled materials (or even reusable or easily transformable) would be used, which have a greater share of the cost of labor, leaving companies less dependent on the volatility of the price of raw materials and more dependent on human labor. This would also protect companies from geopolitical crises and help them with regards to their supply chains, which are more likely to be destroyed or damaged by climate change. Ultimately, this new model would make companies more resilient - that is, it would make them more resilient and prepared to deal with unanticipated changes.

The circular economy model favors new business models in which products are rented by customers over different time periods, depending on the type of product. This gives companies that sell a product or service the opportunity to learn about their customers usage behaviors, as they can come into contact with them more often.

According to the European Parliament, in their draft report for the new action plan for the circular economy, an increase in employment was estimated that could lead to 700,000 new jobs by 2030.

With the circular economy, consumers will also be able to have more durable and innovative products capable of saving money and improving the quality of life. For example, reusing light commercial vehicles rather than scrapping them could lead to material savings of € 6.4 billion per year (around 15% of the expenditure for the same materials) and € 140 million in energy costs, with a reduction in greenhouse gas emissions of 6.3 million tons.
Ultimately, this new model could improve customer satisfaction and loyalty, and also improve the development of products and services that better suit customers. In a market where suppliers remain responsible for the product supplied for a longer period, communicating well and understanding customer preferences and needs is very important.

1.7 BARRIERS TO THE IMPLEMENTATION OF A CIRCULAR ECONOMY MODEL

Implementing the circular economy has, as we have seen, various benefits for the economic and environmental ecosystem. However, there are a few reasons why it hasn't caught on much in recent years and has grown so slowly.

Economic Barriers

In our economic system, there are some limits to the implementation of a circular economy model, such as:

- The social and environmental status is not taken into consideration when it comes to the monetary and economic situation. In a world based predominantly on the economic state it is difficult for this information to be considered.
- Commodity prices are currently low priced and very volatile
- The demand for renewable and reusable products is low
- At present, there are not many professionals qualified in information and communication technology (ICT).
- It is difficult to develop a circular business model compared to the current model

Institutional Barriers

When it comes to a circular economy implementation there can be several institutional barriers such as:

- The fact that the current system is based on the demand of the linear economy and is not yet prepared for the circular economy
- Different business models are difficult to implement because there are still no laws that can allow their development
- Many businesses are based on old trade deals and alliances and are hard to break up to close the loop
- Many business models have the concept of earning in the short term, so it is easier to focus on a product that has a short duration rather than a long term one.
- The GDP index does not consider social and environmental issues, discouraging the creation of value in both of these areas.

1.8 THE BUSINESS MODELS OF THE CIRCULAR ECONOMY

The business model describes the ways in which an organization can create, distribute and collect value and at the same time capture the right value from the market to achieve business objectives.

Lacy, Rutqvist and Lamonica found five business models with which to achieve sustainable development goals in the circular economy. These models are an opportunity to produce value and increase profits, reducing waste, improving performance, building customer loyalty and efficiency.

According to the authors, respect for the surrounding environment does not conflict with economic growth, but is a complementary objective to that of increasing turnover and profits. This thought goes substantially against that of the past generation, which did not feel close to most of these issues. At present it seems that the economic aspect is more important than the environmental one, but the environmental movement that has been emerging in recent years is not negligible.

There are five business models to consider:

1 Circular supply chain "from the very beginning"

This model starts from the extraction and production phase, with renewable raw materials, also called 'biological nutrients' as they are degradable. The problem for this business model is the backwardness of the technology and the costs used to create economies of scale necessary for production

An example of this application is the Ecovative project by Eben Bayer and Gavin MacIntyre of the Rensselaer Polytechinc Institute, who discovered how to replace plastics with rigid materials created by mixing agricultural products. The material obtained is capable of competing in terms of price and quality, compared to fossil alternatives with significantly less energy used. The project won the PICINIC Green Challenge in 2008, obtaining international fame and funding of 500,000€.

2 Recovery and recycling

This model is perhaps the best known and is based on the recovery and reuse of waste products. This modality has different embodiments, it can be used as a closed circuit but also as an open circuit, where the materials that have been discarded are resold as raw materials. The advantages are obvious: cost reduction, waste management, reduced environmental impact and the possibility for customers to be able to sell their waste products

An example is the idea of the multinational Mark & Spencer which has decided to collaborate with the non-profit organization Oxfam. Customers can bring items and clothes purchased in M&S to Oxfam stores. Customers get vouchers in exchange, while the clothes are recycled and the proceeds used by Oxfam to fight poverty in the world, in order to pursue a double objective: environmental and social.

3. Extension of product life

In recent years it has been made known how much companies plan the life of a product, especially in the tech sector so that a customer can buy back a new model by increasing earnings. The extension model instead goes in the opposite direction trying to give as much value as possible to each unit consumed. Making the life of the products longer and allowing continuous updates. This model is experiencing ever greater success over the years given the costs of labor and re-production. It has always been cheaper to buy a new product than to repair it, but given the latest developments in emerging countries like China where minimum wages have increased, it is reversing the trend.

An example for this model is EcoATM, a project by Mark Bowles, which installed automated workstations ready for the purchase of used electronic devices of all kinds. The consumer inserts his device into the machine, the latter prepares a quote and proposes the transaction to him. This operation, according to Mark Bowles himself in 2014 alone, allowed to recover 250 tons of devices composed of toxic materials, more than 30 tons of copper and 700 kilos of silver.

4. Sharing platform

This model is linked to the sharing economy, it is based on the use of a platform that can allow people who want to allocate their consumer goods to potential customers. The platform allows access to many people by sharing access. The sharing economy is very useful because it allows to reduce the use of resources and the environmental impact.

In my opinion it is an excellent business model because it allows ease of use, reduced access price, quality according to pre-established standards and confidence in sharing the product. To these points, certainly many positives, if some negatives are compared, such as the birth of some jobs without secure income and without the classic benefits of a traditional job, just think of the case of Uber, aimed at sharing "steps" and cars. A platform that allows great benefits to the customer but less to the worker, without considering the market segment in which it is inserted, discouraging people who drive taxis.

5. Product as a service

The latest business model includes the purchase of services.
Companies own the product and offer it to customers through rent or lease paid for on a consumption or performance basis. In this way the consumer becomes a user (consumer to user) and the costs related to

maintenance are up to the producer. This model is perhaps the easiest to implement because it is applicable to most sectors.
An example can be platforms such as Spotify, Youtube, Netflix, Amazon Prime that allow you to rent music or videos with an annual or monthly fee.

Right now, the circular economy offers many opportunities to achieve economic and environmental objectives. However, there are some non-negligible challenges that these new business models present, first I gave the example of Uber but also a product like the Kindle can bring benefits and problems. This product is capable of saving millions of trees and therefore alleviating the problem of deforestation but at the same time it has received much controversy for the violation of workers' rights and pose a risk for all those small bookstores and stationeries that have always sold books.

The real challenge is therefore to reduce waste and pursue the circular economy without neglecting fundamental human rights and wondering if the company that offers that product or service following the principles of the circular economy is doing it for environmental terms. or cheap. This will hardly happen alone, but will be the various states and administrations through incentives and forms of regulation.

1.9 THE IMPACT OF CLIMATE CHANGE ON THE EUROPEAN UNION

To combat climate change, the EU is committed to achieving climate neutrality by 2050. This target will become legally binding if Parliament and the European Council reach an agreement on European climate law.

The climate law is part of the European Green Deal, the EU's statement towards climate neutrality. The European Parliament has for some time already given importance to more ambitious goals for the fight against climate change. MEPs called for the 2030 emission reduction target from 1990 levels to rise from the current 40% to 60%, and pushed individual member states to achieve climate neutrality by 2050.

In the figures below, we can see the progress of the European Union.

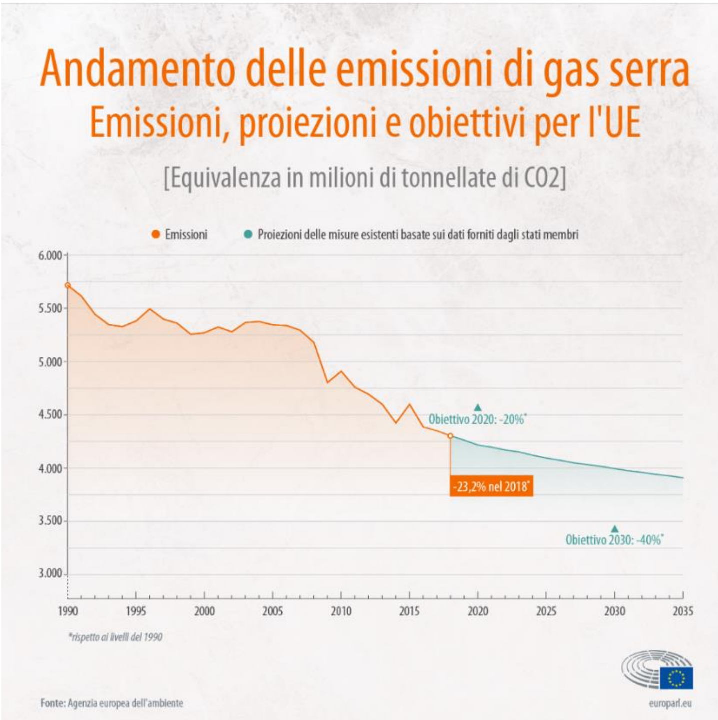

Figure 2: Trend of greenhouse gas emissions, Jan Huitema (2020).

About 60% of the EU's total emissions come from transport, agriculture, construction and waste management. The target for reducing emissions is 30% by 2030 compared to the levels of the year 2005.

The reduction will come through the agreed emission targets of the various nations which are calculated on the basis of the gross domestic product (GDP). Low-income EU countries will receive help.

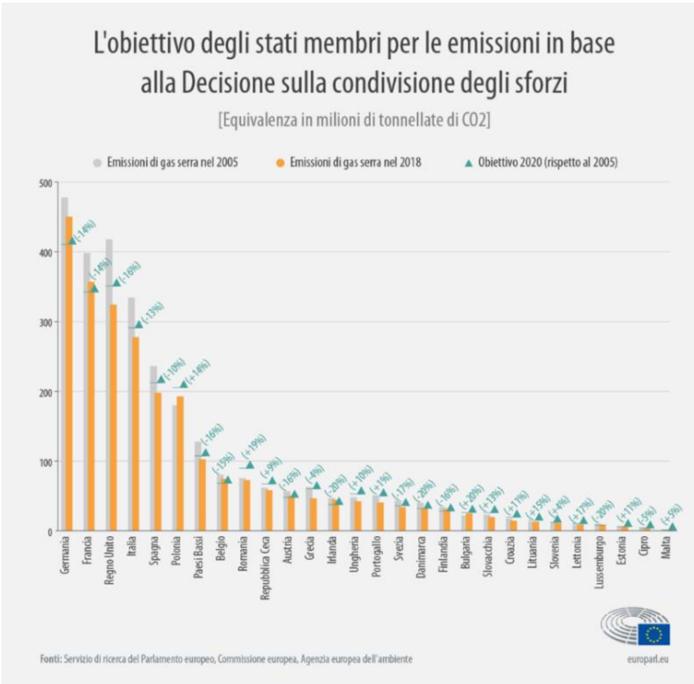

Figure 3: CO_2 emissions by Country, Jan Huitema (2020).

1.9.1 The importance of a response from Europe

Climate change is already affecting Europe in various ways, leading states to loss of biodiversity, fires, crop failures, increased storms and temperatures. Climate change also has a huge impact on people's health. According to the European Environment Agency, the European Union is the third largest producer of greenhouse gases after China and the United States.

The EU is a key player in talks with the United Nations on climate change and has signed the Paris Agreement. All EU countries are signatories, but their positions and emission reduction targets are being grossly assessed by the EU. The EU fights climate change with a clean energy policy, the focus is on increasing the share of renewable energy consumed by 2030 to 32% and creating opportunities for people to produce their own green energy. The targets for renewable energy and energy efficiency will be reviewed as part of the Green Deal.

" By 2050 we will consume as if we had three planets. As our natural resources are limited and the climate is changing, we need to abandon the current 'take, produce, throw' model and aim for a circular economy. Today Europe is in full recovery from an unprecedented health and economic crisis, which has highlighted the fragility of our resources and value chains. We should take advantage of this momentum and address the problems that hinder the success of circular solutions."

These are the words of Jan Huitema, speaker of the latest action plan for the circular economy.

The new European Union Action Plan for the Circular Economy (CEAP 2.0) is integrated into the climate objectives agreed in the Green Deal and the Paris Agreement. While the first action plan for the circular economy of 2015 focused on the recyclability of materials, the second plan gives priority to the preventive actions to be taken, in the context of waste prevention and management. The reference goal is to halve the use of resources by 2030.

The circular economy will not only drastically reduce CO_2 emissions, but will also stimulate economic growth and provide job opportunities, which Europe needs to recover.

" Currently, the production of materials for daily use is responsible for 45% of CO_2 emissions. To profoundly transform our economy into a circular economy requires a holistic approach, based on appropriate assessments that can provide a decision-making process based on scientific data. To make CEAP 2.0 a success, the principles of circularity and sustainability must be guaranteed at all stages of the value chain. At the same time, innovation plays a fundamental role, as the circular model is based on new, often digital, technologies ", Jan Huitema continues.

According to the draft report on the new action plan for the circular economy by the European Parlament, it emerges how important a response from this community is to allow member states to make progress on this issue.

Some very important elements are taken into consideration:

• **Strategic framework for sustainable products**: Rules will be set on durability, repairability, the possibility of improvement and efficiency in terms of resources and energy for each type of product. It also supports the plan to introduce a passport for digital products in order to monitor environmental consequences

• **Electronics**: It supports the initiative for circular electronics by extending their life cycle, promoting the longevity of products.

• **Batteries and vehicles**: Improvement of collection, sustainable procurement and life cycle effects.

• **Packaging**: Supports the goal of making all packaging reusable or recyclable in an economically sustainable way by 2030.

• **Plastic:** Address the microplastics issue in a comprehensive way. Also, by gradually decreasing microplastics

• **Textiles:** Measures to combat the loss of microfibers. The Commission should propose, in the new strategic framework, targeted measures to reduce the presence of microplastics in the fabrics that the customer buys every day, considering that the percentages are between 1 and 35% in marine litter.

• **Water, nutrients and food products:** Implement the goal of halving food waste by 2030. The reuse of treated urban wastewater allows to overcome the problem of water scarcity by allocating the purified water for agricultural irrigation purposes.

In 2035, Europe will have tight deadlines regarding the 65% waste recycling target in cities and a maximum of 10% for landfill waste. The

European Union should achieve waste prevention objectives and stop sending waste to landfills where alternative technologies are available for their management.

It is important to note that the circular economy does not thrive on a top-down approach and requires smaller local parties and regional authorities to play a leading role in the implementation of the action plan proposed by the European Union. However, the Commission should promote the exchange of best practices on waste collection and innovation in new facilities.

In a society aiming for complete digitalization, consumers and producers are demanding up-to-date and accurate information on the sustainability and origin of their products. The report supports the European Commission's initiatives to introduce a passport for digital products. The environmental impact assessment should also consider the impact of spare parts, semi-finished products, recyclability and the life cycle of a product.

The circular economy has been there for all to see for many years, but without appropriate measures and standards for everyone to follow. There is still no final goal that can be pursued, a common goal. However, some key principles have been defined and can be followed, these principles will be used in particular for the drafting of a materials passport.

2. INFORMATION EXCHANGE SYSTEMS

2.1 SCARCITY RELATED INFORMATION EXCHANGE

As we saw in the previous chapter, we are faced with a significant increase in the demand for raw materials and resources that are limited, this is aggravated by the increase in the world population which consequently leads to an increase in the demand for these resources. The aim is to move away from the linear model being predominant since the industrial revolution to a new model where the lifecycle of product is extended to reduce the use of raw materials and the production of waste.

This process seems impossible to do without various actors in the process agreeing and exchanging information, useful for the continuation of the product's life.

Köhler et al. (2010) investigate material scarcity and possible solutions. They conclude that:

"Resource scarcity comprises a range of multidimensional complex problems, which are sometimes termed 'wicked' problems. Uncertainty prevails due to the fragmentation of the intelligence regarding the

various aspects of scarcity. While relevant information might actually exist somewhere in society or industry it is hardly possible for practitioners to retrieve all relevant knowledge. From a single practitioners' perspective these matters are simply too complicated and cannot be scrutinized ad infinitum. The situation can be interpreted as a sign of insufficient knowledge exchange".

For many years, States have focused on the importance of information exchange of materials. Although all the parties involved agree that a tool is needed that can store the right information, exchange data, where the data is of quality and provided at minimal cost, it has never been reached. a common conclusion capable of achieving this goal.
Another explanation for the lack of data exchange is provided by the literature of Sterr and Ott (2004) according to which the industrial organization was driven by economic rather than ecological reasons. As discussed above, scarcity has never been a top priority and resource prices have only recently risen significantly. Therefore, economically the exchange of material information was not a priority.

2.2 REDESIGNING BUSINESS PRACTICES TO ADDRESS RESOURCE SCARCITY

Practices need to be redesigned in order to fight the scarcity of resources, a tool that plays a fundamental role in the causes is the Material Passport. Since the supply chain has different actors and different roles, we need a tool that connects the various parts. Before talking about the various information necessary to overcome the problem described above, the resources in the supply chain are presented.

The life cycle of a material is represented by three stages:

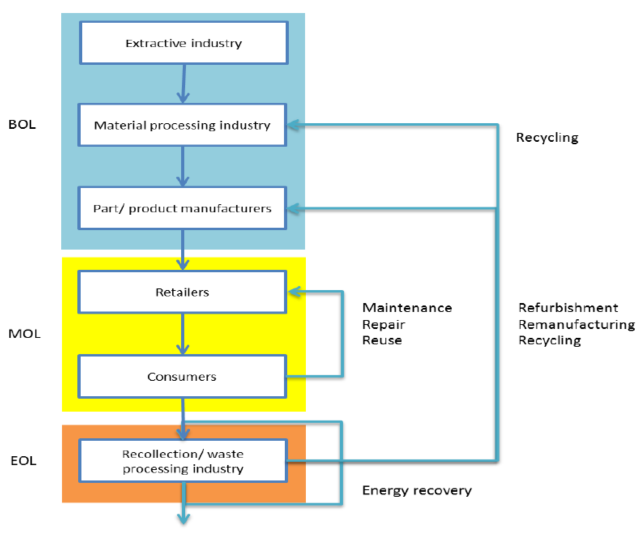

Figure 4: Supply chain actors and resource-related activities. Source: Parlikad et al.

1. Beginning-of-Life (BOL), extraction, product design and finally production

2. Middle-of-Life (MOL), use, resellers and extension of the useful life of the product

3. End-of-Life (EOL), logistics and material recovery

The first point includes the first process for using a product, the extraction. From this process, if needed, the materials are transported from the extractive industry to the processing industry, which transforms them from raw materials to usable materials. These materials are bought by buyers who bring out a finished product ready for sale in most cases. From this point the product is sold to retailers who take them to the reference store to sell it to the end customer.
The recovery of a product begins when its life cycle ends, and it no longer satisfies the final customer. From this moment on there may be different strategies for the recovery of the mentioned material. When the product can no longer be used and cannot recapture its role, it is considered a waste and distributed to companies that can opt for a second use.
The refurbished, remanufactured or recycled materials are then distributed to the product manufacturing industry to close the cycle. Waste processers can also decide to dispose the materials with or without energy recovery. Let's see the various parts of the supply chain.

The mining industry meets the very high demand for all the various materials. The goal is to extract as many materials as possible at a low price, without taking an interest in the surrounding environment. This poses major problems on the scarcity of some materials; and it affects, as we have already discussed, other materials that are related to their extraction. This relates back to by-products but also neighboring forests or fish stocks.

When it comes to closing the life cycle of a material, there will be competition between material extraction and recycling. However, since many products are immobilized in today's use, it may take several years before they can be reused and therefore can meet the demand.

Within the various extraction companies there must be research and environmental experts who have knowledge of the position of scarcity within the company, to address scarcity in the most effective way possible. Finally, information on the circumstances of the environment is necessary to prevent negative impacts on the stocks of nearby materials. This information is necessary to have a more effective production and to direct research into alternative materials.

Information regarding the best production and extraction techniques optimizes the process and helps reduce waste. In addition, end-of-life information is needed to better and more effectively reprocess recycled materials and minimize pollution.

To develop alternative materials, it is necessary to know the specific characteristics and properties of materials such as boiling point, strength, water penetration, etc. This information needs to be supplemented with other information that may be helpful to the cause such as hazard classifications, or the response to manufacturing processes such as welding and the ability to be recycled.

For some materials there are no substitutes and therefore designers have a role to play in the use of materials and in the optimization of the initial life time and end of life system. Material optimization includes: creating products that have a relatively long shelf life, are modular and can be easily maintained. To optimize the end-of-life system, products should be designed in such a way that they can be easily separated, reconditioned or recycled.

They also need information on the properties of the extracted materials, such as strength, hardness, flammability etc. to be able to decide if the materials can be assembled and combined, so as to be able to identify possible substitutes and evaluate the possibilities of end of life. Information on the composition of the components of materials purchased from suppliers is necessary to prevent contamination and optimize the prolongation of their life. To be able to balance needs, designers need to be in close contact with management in order to get an indication of what priorities are within the scarcity problem, given a certain strategy, time frame and budget.

To address scarcity, the final consumer also has a key role, especially as regards the maintenance and reuse of a product. For example, by repairing a product or recycling various materials once their life cycle is over. From this moment on, the material takes a different path depending on the situation, it is important to have a high recovery of materials. The materials are separated as much as possible to avoid contamination and optimize the process. This is a very special action because a comparison must be made between the cost of recovery and the benefits of recovering the material, a qualitative and quantitative work is required.

To improve an efficient and effective harvesting process, it is necessary to know the physical properties and components of the product. Like this, other information about the physical structure is also necessary, such as the size, weight and components that compose it. This information is used in the division process to be retrieved in the best way.

In addition, some of the information described above gives an idea of the value and how the components can be placed and used. Information such as the composition of the products, how it is produced and how to be disassembled are important in deciding the best way to recover it.

Starting from the history of a product, when it was born, what its changes have been over time, it is possible to study it in depth, estimate its life expectancy of its components and the possible reuse is easier. It is deduced that in order to increase the quantity and quality of the recovery, a level of information is needed that the products do not have yet because they do not have a tool that allows the exchange of information between the various parties.

Very often some actors have only one piece of the puzzle that does not allow them to understand the product in its entirety. In this case it is urgent to find an instrument and more generally a coordination, an organization or a government that can organize the information is needed.

2.3 CHARACTERISTICS OF INFORMATION EXCHANGE SYSTEMS

After defining what information is needed, we have to see how it can be exchanged. There are three factors that influence information sharing: a common view with the entire supply chain, trust between the parties and uncertainty of suppliers. The first two do not need explanations, because they are present in most of the operations.

The uncertainty of suppliers in managing information meanwhile will negatively impact the entire supply chain. Overcoming this barrier requires a partnership between the various parties, a set of principles and sometimes a written contract that testifies to the correct exchange of relevant and sometimes critical information.

Business globalization is also a trend in the supply chain. Companies tend to extract and distribute materials globally to maximize earning opportunities and reach a larger community, on the other hand this increases coordination and logistics costs. Currently, large investments are therefore necessary to allow companies to communicate on a planetary level and therefore can be coordinated. However, technology over the years has made enormous strides, allowing this result at a limited cost, the Internet, for example, has greatly improved and facilitated communication between various companies in different parts of the world at a click, especially if shared information is extended to the internal warehouse and procurement processes.

Since they are sensitive data for each company, there is the possibility to locally store the data within, for example, a server within the company itself and to transfer them only when necessary through a pull function of a centralized database or of third parties. “The data trustee acts as an escrow agent, retaining the plaintiff's data until a legitimate need for investigation arises. They provide more data administrators, so that companies can choose who to entrust their data to. " (IntertrustGroup 2020).

Ultimately, we can identify the following five elements as critical to the success of a resource passport:

- *Provision of the information*
- *Storage of the information*
- *Access to the information*
- *Quality of the information*
- *Presentation of the information*

2.4 CONCLUSION

Although the scarcity of resources was added to the international agenda years ago, the right attention and priority was not given to the topic. Now, the scarcity of resources has become a problem that can no longer be neglected, due to the continuous waste in the various production processes and this will not allow the economy to grow as it has always done in the past centuries. The concept of circular economy derives from multiple schools of thought already consolidated. To summarize the principles already discussed in the previous chapter that make up the circular economy are:

1. The redesign of products and production processes so that they can be in closed circuits with little or no impact on the environment and human health.
2. The implementation of end-of-life systems for the flows of resources and products.
3. The creation of a national network for the exchange of materials.
4. The collection and especially the exchange of information related to the status of a product and its components.

Many changes have taken place over the years and this seems to be a very dear topic to the zeta generation. With more and more events such as ‘’Friday for future’’ as evidence of a problem felt on the skin of everything, but it is not enough. Resource scarcity is not a priority for governments, business owners and multinationals.

In order to develop a new system, you need to do something that has never been done, and require the presence of many people for it to be applied.

The lack of priority is one of the reasons why it has never been put into practice. In order to adopt a tool such as the Material Passport it is necessary to identify which actors will have actions to perform and which responsibilities.

The roles and information needs are different within the elements of the supply chain. This overview addressed in this chapter allows for the identification of the contents of a resource passport that will guide the rest of this research. In identifying how a Materials Passport is composed, five elements are important to its success: provision, access, storage, quality, and translation from a complex to a simplified presentation of information. The theoretical information gathered on these five factors that make up a passport is evaluated in the next chapter.

3. MATERIAL PASSPORT

3.1 INTRODUCTION

There is still discussion on the potential impact of circular economy on climate goals. However, there is increasing evidence that the circular economy can help prevent climate catastrophe and help society effectively reuse resources. In the meantime, digitization has impacted many areas of our professional life and beyond.

In the Fourth Industrial Revolution (IR 4.0), the digitalization of products information will become even more important. In order to implement the Circular Economy Action Plan, the European Commission is outlining the key principles to regulate many aspects of product life, improving repairability and durability. One of the aspects mentioned in the Action Plan to digitize the life of a product is the use of a digital passport.

Now, the lack of precise information makes it impossible to quantify the circular initiatives. On the other hand, there are several discussions on the type of information needed to achieve the circular economy. A missing piece of the puzzle to implement this process is digitizing products and processes to analyze the life cycle of a product.

The circular economy in recent years has been gaining more and more importance for businesses. There are several examples to consider such as the Ellen MacArthur Foundation, a charity dedicated to promoting the circular economy. To address the Climate Emergency, I believe that a Circular Economy is a necessity, not a choice.

Research to date has largely focused on gathering data on new products, for future reuse. However, 80% of buildings that exist today will still exist in 2050, so it is imperative that we make the most of the materials already in existence (Kevin Adler). For a correct transition through the circular economy, it is necessary to go through the sharing of information through tools that are not yet implemented today.

An element that could provide the necessary methodology is the Material Passport. These digital materials allow with a simple sharing an easy supply of information that facilitates the gap existing between the various players in the industrial chain, from producer to consumer.

This thesis allows to have guidelines regarding the possible adoption of these digital tools capable of optimizing much of the waste and inactivity of information. In this chapter we will go to see what are the opportunities and obstacles that the Material Passport can encounter in the path that led to the circular economy.

3.2 INCREASING CIRCULAR ECONOMY TRANSPARENCY WITH DIGITAL TECHNOLOGY

To overcome the challenges that lead us to the circular economy, digital passports and blockchain technology can offer opportunities for traceability, reliability and security for products on a global scale.

For this reason, the Ellen MacArthur Foundation states: "With current advances, digital technology has the power to support the transition to a circular economy by radically increasing virtualization, dematerialization, transparency and feedback-based intelligence". Digital solutions can give information on the traceability of a product to know exactly where it is as it currently happens in the most advanced warehouses and provide easier access to products and services. This will allow for more transparency on what happens to enable the digital circular economy.

Access to data will also allow you to understand whether a company really has the goal of achieving process sustainability or is pursuing it only for economic reasons.

Technologies such as the Internet of Things (IoT), digital twin, and blockchain / distributed ledger technology (DLT) can help track products and materials, thereby increasing reuse, repair and refurbishment.

The Circularity Gap Report 2021 has proven itself in favor of the use of information technology. In this case, IT is ideal for tracking and improving resource use and providing information to every stakeholder in the supply chain. More specifically, a digital Material Passport can provide information from the various players in the supply chain, on the materials that compose it, on the social and environmental impact.

3.3 WHY IS A MATERIAL PASSPORT NEEDED?

According to United Nations estimates: ‘’construction accounts for some 50 percent of raw material consumption in Europe and 60 percent of waste”. The fact is that the Earth is a closed system, and this situation is unsustainable in the long run. There is an urgent need to use raw materials even more intelligently, benefiting from the use of more effective and less material materials, ensuring a longer life for the latter. The Material Passport gives material an identity. First of all, it affirms that the material exists and establishes that the material receives and maintains its value, also through the deconstruction of the same.

Like a personal passport, the Material Passport allows the material to ‘travel’ and identifies the past destinations that allowed it to be there at that moment, of the same product or of a new one made up of the previous one. In general, Material Passports create incentives for suppliers to produce and developers, managers, renovators to choose healthy, sustainable and circular products. They fit into a broader and growing movement that aims at developing circular building business models.

Just as a passport gives personal information, Material Passport does the same for the reference product. As Dutch architect Thomas Rau says: “waste is material without an identity”. By 2060, the land area of built property on the planet is expected to double. This would mean an additional 230 billion square meters in new construction, or the equivalent of building the current floor area of Japan every single year until 2060. (Block et al. 2020).

If we could find a way to reduce energy, labor and transport costs of new materials, it could be eliminated and therefore also their emissions.

That's where materials passports can help.

3.4 WHAT DO MATERIALS PASSPORTS LOOK LIKE?

Materials passports are defined as:

"Digital sets of data describing defined characteristics of mate rails and components in products and systems that give them value for present use, recovery and reuse MPs are an information and education tool that addresses questions often no covered by other documents or certifications related to building products, especially in relation to the circularity of products MPs do not address the data output and are not an evaluate of data. Instead, they provide information that supports the assessment and certification by other parties and allows existing assessments and certifications to be entered into the passport as uploaded documents.

In brief, a materials passport is a digital report containing circular economy relevant data that is entered into and then extracted from a centralized database in the form of reports customized to the needs of diverse users" (Luscuere and Muhall 2017).

The overall goal of a materials passport is to document materials present in a product to maximize reuse potential. This type of document provides information on the material in question as if it were a table of a food, the difference is that the passport requires much more information than just the "ingredients". This document must demonstrate the components but also the journey made, where it was born, the current situation always associated with the environmental impact. If this sounds like a lot of information, it is. As data continues to grow, the passport becomes more complex and cumbersome to manage. Complexity is one of the key challenges of Materials Passports, but it also presents a unique opportunity. This elaborate level of information allows owners to understand what is really behind a product and its economic and environmental value.

The Material Passport can be applied to every product. There are different levels in which a product/construct can be discomposed:

- Material level
- Component level
- Product level

For example, for a building, a Material Passport could be a complete description of all products (staircase, window, furnace, ...), components (iron beam, glass panel, ...), and raw materials (wood, steel, ...), that are present in the building. Ideally, this database is created during construction and subsequently continuously kept up to date.

A passport allows the owner to know exactly what it is made of, so that it can be reused for future use of the materials. It allows the owner to view a product/construct as a depot, inventory of valuable materials.

Another possibility is that a Material Passport enables the owner to get a better overview of value of the product.

3.5 RELATION WITH CIRCULAR DESIGN

Of course, simply recording what ingredients make up a product does not guarantee that those materials can be reused. It is necessary to add and specify all the materials that make up a product, the material passport can also say how sustainable, recyclable and healthy the product can be. These documents can be powerful tools to encourage the re-use of components and recycling of materials, as well as encouraging the use of materials which are environmentally friendly and not over-exploited. If construction is being planned with circularity and sustainability goals in mind, a materials passport can serve as a prompt at the design phase to ensure that buildings are using components that can be easily and safely reused.

Merlijn Blok, Built Environment Consultant at Metabolic, says Materials Passports play a particularly valuable role at the design phase. *"Material passports support architects in conceptualizing buildings as material banks from which valuable products can be harvested after the buildings, or part of the buildings, become obsolete,"* he says. *"By designing for disassembly and archiving information on the materials we're adding to our built environment, architects can play a crucial role in sustaining a waste-free circular economy into the future."*

To start and continue the momentum of the circular economy, an exchange of information is increasingly necessary, which is as detailed as possible, and which relates to the specific product. A non-negligible aspect of this story concerns the ecosystem which is composed of the material passport platform (MAP) which is associated with building information modeling (BIM) in the example of the buildings.

Ordinary home owners also benefit from Materials Passports. Buying a new home that has been lived in for many years, as well as a used product, is made much easier if there are tools that allow you to recognize the status of current products and innovations made over time and be more objective and safer in your choice.

This access of information will facilitate not only the house market, allowing an even more massive use of used products at the expense of new ones. A discourse that can be applied perfectly to homes and buildings: people should be more willing to buy a home or apartment if they know exactly what materials are inside, where they came from, and just how environmentally friendly they are. The better we can record the history of the materials, the further down the supply chain the incentive spreads. These incentives can also be encouraged, for example by providing tax benefits to buildings with reused materials.

3.6 ADVANTAGES OF MATERIAL PASSPORT

In recent years, a solution to a problem of great importance has been sought. A possible solution to this problem is the closure of the material life cycle. For this reason, the European Commission has launched an action plan to make the circular economy viable and reduce emissions.

In the circular economy, materials are used as long as possible, keeping their value high. The materials are valid if not functional, attractive and accessible. To better develop the transport of materials, a lot of information is needed by different actors in the value chain. Not all the information is necessary for all actors which may be useful for a certain stage in the life of the material. Some types of information are not needed in a stage but may be needed for future use.

Some of the benefits that can come from future use are:

1. Continuous use of the various materials with value if not the same very similar to the initial state.
2. Incentives in companies to produce quality, sustainable products that follow the circular economy
3. Develop a circular economy and material recovery
4. Reduce the eco-footprint
5. Make it easier for customers to buy sustainable products

6. Assessment of future material flow
7. Management of supply and demand
8. Assessment of secondary raw material
9. Acquisition of relevant data for suppliers and companies
10. Reduction of unused material and waste management costs
11. Materials cycle development
12. Elimination of waste and use of virgin materials and provide a tool to abandon the linear economy by embracing the circular one
13. A more granular understanding of the product might enable novel forms of financing that will support suppliers to provide a service rather than sell a product.
14. The recovery of a collateral in case of default might improve through the sale of the parts instead of the product as a whole.
15. Others

Table 2: Business opportunities for the use of MP

Business opportunities	**Aspects of Materials Passport**
Circular index	Know product performance in the circular economy
A differential market	Opportunity for company and manufacturers to stand out for transparency or circular potential of their products
Increase traceability	Opportunity to track volume, quality, location and other specifications
Decrease environmental footprint	Waste production and demand for new raw materials will be reduced
Supply security	Passports provide conditions for the reliable recovery of materials, ensuring material residual value

Secondary materials market	Take control of material value streams, increase residual value and reduce material flow uncertainty
New business models and partnership	Reversibly designed products and systems may interest to property and business models for leasing and material banks
Enable operations	Circular design can enable assembly, disassembly and material production
Guide users	Inform users about installation, maintenance, cleaning and reuse possibilities to keep products in recoverable condition

3.7 THE DOWNSIDES: WHY MATERIALS PASSPORTS ARE NOT YET UNIVERSAL

As interesting as Materials Passports are, they could not be perfect.

Integrating a powerful new tool which will have such profound impact and brings serious challenges.

Lack of a unified approach

Many parties are designing the famous passport for their own personal purposes or simply for their use, with different types of documentation, different visions and objectives. Although this does increase complexity, this is not an inherent problem as long as these passports are able to communicate with each other. If, for example, a re-used beam is traded between organizations which use different standards, then the information will need to be translated. There is no perfect passport, since there will always be a trade-off between detail, time and cost. There are initiatives aimed at solving the challenges of unification, but it will take engagement from the construction sector, government, and industry with a period dominated by trial and error.

Keeping up to date

A good passport always needs to be updated and changed, this could be a challenge for different managers and for companies. If they repaint the product, what paint did they use? Where did they get it? Maintaining a high level of detail can be difficult over time.

Privacy and security

Everyone's personal passports should be kept safe and secure. So even the passport of materials and in a world that is turning to digitization is not a simple process. Clear sharing and privacy guidelines on the information in the passports and how to share it (and with whom) are essential for making optimal use of a Material Passport's value. Finally, the information needs to be trustworthy. This requires investment in an independent agent that everyone can trust, or a system like blockchain which makes earlier information almost impossible to retroactively edit.

Early adopters

The market for secondhand materials is still in its infancy, and currently not able to support the optimal re-use of the materials in a building.

Also, much more standardization, at least at the level of components, will be needed to increase the re-use the materials in a product.

Legislation

Legislation needs to be put in place, to support more sustainable product, enable the development of services instead of ownership and support a broad deployment of Material Passports.

3.8 CURRENT SITUATION OF MATERIALS PASSPORTS AND SIMILAR

The European Union is starting to take steps in the direction of the sustainability of industrial processes, especially in the battery sector, this works hand in hand with industrial innovation and the creation of new business models. There are building blocks, such as the Green Deal, which aim at standardizing the battery industry. The goal is to ensure that the products found on the market are high-performance, have a low environmental impact and are safe. While it is true that we will move towards a lower environmental impact, by decreasing emissions, it is also true that this will lead to a substantial increase in the demand for mineral raw materials: almost 60 times for lithium alone and 10 times in the case of other earth elements rare by 2050. A key element in this process will certainly be the reuse and recycling of batteries (World Energy Outlook Special Report). The goal is to achieve excellent recycling and recovery rates for a large amount of precious resources such as cobalt, lithium, nickel and lead. The collection of these materials will allow the various states to be less dependent on certain critical materials while thinking about environmental sustenance.

To achieve this, it will be important to introduce the Battery Passport, for secure data sharing and greater transparency in the battery market with increased traceability. This is one of the flagship products of the

Global Battery Alliance, it was conceived as a solution for the secure sharing of data allowing the efficiency of resources in their life cycle. This digital representation of a physical product becomes important for a move towards a circular economy.

We can consider this representation as a digital twin of a product, in fact it contains various information that are useful for making decisions on production or recycling of that particular product. This system, in fact, allows to have information on the history of the product, on its life cycle, allowing to be able to decide objectively and validly on its state of reuse and recycling.

The Battery Passport is required because it clarifies the conditions under which a second customer can reuse the battery. This system will bring significant benefits to customers, and if it achieves certain goals set by industry initiatives, it will also bring significant benefits to the parts that make up the battery value chain.

Another example of digitization that has the circular economy as its purpose is the Material Passport supported by Building Information Modeling (BIM). BIM is a shared resource that includes information about a structure, the latter will be used for future decisions during the life cycle and is a digital representation that can be shared on the physical and functional characteristics of a given object.

A BIM model has data on the geometry, quantities and properties of building elements, cost value and material inventories, and therefore contains important data, necessary for design, fabrication and construction activities.

The BIM-based Materials Passport has many roles throughout the life cycle of a building by giving a comprehensive life cycle assessment (LCA) of the building's sustainability.

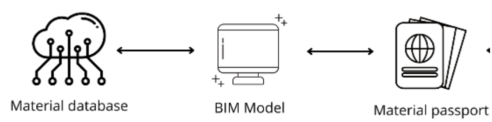

Figure 5: BIM system

To date, automated information exchanges between BIM and LCA have not yet been developed, only some BIM-based object libraries provide information that is useful for the design and standardization of materials, such as BIMobject (2019). However, this information exchanged between the two parties complies only with national or corporate standards, therefore their international application is limited.

Focusing on the digitization of material information has had a great impact, as demonstrated by the adoption of the International Material Data System (IMDS), used by a large number of users in the global automotive industry. This tool is used for the immediate transfer of information along the supply chain on each material that makes up a product. In this case, the goal of IMDS is to aggregate all the information that is useful to meet the requirements of the European Directive on end-of-life vehicles. IMDS is also used to improve the reduction of hazardous materials in vehicles and the increase of recycled material.

The strategy of the European Union is that the Material Passport is able to provide information on the origin, reuse, composition of the product and information on management at the end of its life.

The first example of a mandatory digital passport is the one of batteries launched by the European Union, which uses the information obtained with the aim of the circular economy. However, there are initiatives that aim at the standardization and digitization of products, an example is the fact sheet on the circularity of products in Luxembourg. This tool aims at standardizing product information and data.

In addition, there is the European SCIP database for all substances that are considered problematic, this system is a kind of public database, which has the possibility of giving information on the composition of each product. Then there is the European Union initiative for all safe and sustainable design objectives, this considers the entire life cycle of the product and is working on objective criteria that can be applied to all products and industries in question.

Combining all these examples the Materials Passport would gain significant benefits in its introduction in all markets and could also play an important role in informing consumers about their purchasing decisions.

There are tools that have links to the material passport. These tools are represented by environmental indicators such as life cycle analysis (LCA) and environmental product declarations (EPD). There are also tools similar to the materials passport but with a more specific use by sector, such as building passports and electronic building passports. The Building Passports is a tool for communicating the sustainability performance of a building and which at the same time gives information on the quality of buildings, on environmental and performance properties. The Electronic Building Passports is similar, but emphasizes the use phase. The Energy Passports focuses on energy impacts such as energy needs and related emissions.

While there are such good examples, Materials Passports has a different scope than these initiatives. It focuses on material value recovery and product maximization, including material health. All information in the material passport is supported by measurements on the environmental impacts they have.

3.9 MORE THAN AN INGREDIENTS LIST

An interesting similarity for the materials and compositions for the products are the food items that we buy every day. The tool described in this chapter, however, does more than just provide a list of ingredients, here's what sets it apart:

The products and materials that compose it are complex

Product chains are often complex (Kaplinsky et al.) and this is important because it defines the composition of a product.

The products usually consist of different parts purchased from suppliers, which in turn can be purchased from sub-suppliers and so on.

A finished product can be described in most cases by chemical identifiers, of which there are 125 million for substances. This demonstrates the complexity of the situation is that transcribing all the various substances would not be a practical reality, and if it were, one wonders if all this information would be useful for circularity objectives.

The context of a product in its application is important

It is essential to know where the materials that make up a particular product are and its location. This allows us to understand where the resource used comes from, where it is extracted and by whom to check for any problems and attribute them to the direct cause. It is also helpful to understand how materials are extracted without losing their potential for reuse or recycling (e.g. through contamination with other materials).

Volatility and dependence on the monetary value of materials.

Finished products are worth multiples of the value of their raw materials. This value obviously depends on the reference market. Having an idea about the cost of raw materials shifts the attention to a different element, based on basic materials rather than on final production. Currently, the price of raw materials is calculated backwards from the finished product.

The products change during use

During the use of a product by the customer, it may receive transformations that alter its normal value and use. In fact, the most used products change frequently and wear out. Keeping track of these changes is a very important factor in having up-to-date information on the product and its current value. The latter may have different functions once its normal life cycle is over and based on this information in our possession we have a concrete idea. The Materials Passport provides material health information that can be used for disassembly, uninstallation, disposal, and so on.

In this case, the reference model having to cover different functions also has different tools that must be used:

- Material Passport
- Assessment tool, data management and assessment of the various functions
- Eco inventory, material-specific fixed data. This is an important tool because it takes away several responsibilities from business owners who will add product data to the platform and makes the process more standard

  Spreadsheet, component layer, specific and evaluated. It allows you to have all the information just a click away

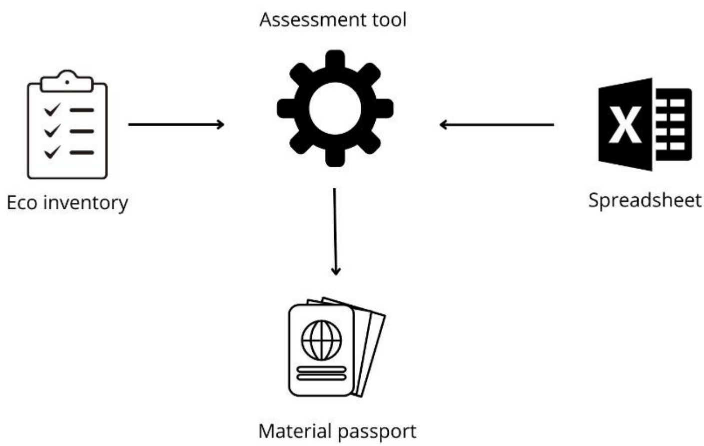

Figure 6: Framework for MPs model

3.10 CONCLUSION

The rules described by the circular economy are a promising option for achieving global climate goals and moving towards a better use of resources. The movement towards the circular economy would have a positive impact on companies to increase their value and above all an impact in reducing carbon emissions, favoring the environment and society. For this reason, the institutions promote initiatives that lead in that direction. On the other hand, the transition to the circular economy imposes higher requirements on companies and products to be compliant and sustainable. These companies will be put to the test because given the ever-increasing number of regulations and requests for reports and data on materials, certainly increasing costs.

The Material Passport is a means of obtaining the required transparency by increasing traceability and efficiency, giving information on a given product in real time, in the phases of its life cycle and to all the actors involved.

There are still some limitations to overcome for this tool to take hold and become fully applicable. With the European Union's request for a passport for batteries in the draft EU regulation on batteries, the goal is progressing in that direction. To continue, one wonders where further implementations are needed for research and stakeholders.

When considering Digital Passports, several approaches are discussed and proposed. At this point it remains to be asked whether the Product Passports are easily usable by all actors and give the correct information to the institutions in the design, procurement, production and purchase phases. The digitization of product data and simplified access to information for all stakeholders are a fundamental factor for the transition and scalability to the circular economy. The discussions described in this chapter analyzed if the Material Passport could be a central element of the circular economy and as such needs to be further developed, through collaboration across the entire industry chain.

4. MATERIALS PASSPORT'S ARCHITECTURE

4.1 RELEVANT PARAMETERS

By analyzing the situation, it is possible to identify the main parameters that influence the recyclability of a product. A first element to take into consideration is the mass of a product, first of all because the heavier a product the more difficult it is to dispose of and secondly it generates a considerable volume of waste.

Another element to take into consideration are products made up of incorporable or separable materials. Separability is important in this sector as the materials that are bonded together are difficult to separate and therefore a reduction in the recycling potential.

The lifespan of a product also needs to be considered, because it is materials with a short life that have to be replaced more often during their life and thus create a large amount of waste.

The environmental impacts that a product has must also be considered, given that some products are avoided in terms of sustainability. The parameters necessary for the optimization of the ecological impact were adopted by the IBO standardized LCA procedure (IBO, 2019).

The ecological impact is assessed on the basis of the LCA methodology and the IBO repository, which considers the three parameters GWP (Global Warming Potential), AP (Acidification Potential) and PEI (Primary Energy Intensity).

These parameters have been highlighted primarily on a work based on buildings because at this time the most advanced compared to other sectors, with the possibility of being able to expand, as we have already seen, to other sectors that need this work to bring the circular economy to the next level.

4.2 PROPOSED ARCHITECTURE

The circular economy lags behind other sectors in terms of digitization, the challenge will be to create a process that makes digitization as simple as possible to allow an easy use to all the actors of the value chain

The ever-faster innovations offer great implementation opportunities for the circular economy. The large number of information that needs to be collected, processed and used, need a mechanism capable of making it friable to a good number of people and companies by creating the Material Passport (fig.8). This needs to be integrated into a material database to provide reversible information and circular design, it will become a digital tool because it can store information of individual components throughout their life. The material passport and material

Figure 7: Material Passport's communication between manufacturer and material database

database can be seen in combination and complementary for this use (fig. 9).

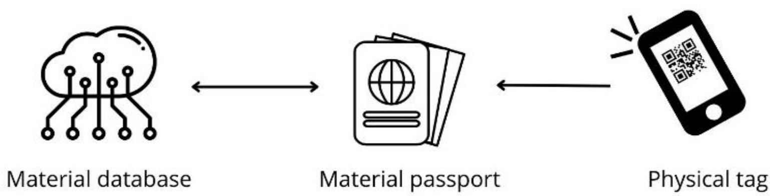

Figure 8: Material passport's tools

4.2.1 Database

The analysis of material flows and stocks is essential for identifying supply and demand for materials and bringing them into relationship to one another. This allows for strategic decisions within the supply chain, especially when reusing materials and components.

Intelligent networking (connection of devices with the internet and communication between devices- also known as Internet of Things (IoT)) can be useful when incorporating automated data collection devices (e.g. remote sensing) or monitoring equipment that exchange information on with corresponding Materials Passports. This could include monitoring data on consumption (e.g. energy, water) or exposure of products to estimate exchange intervals, service life, main tenancy requirements or second life options.

For an effective use of IoT, the development of Artificial Intelligence (AI) plays a vital role. AI can be used to assess information based on patterns (e.g. for information transfer) or when collecting data. Within the machine learning process there is a possibility to identify material composition in an automated way in the future.

Furthermore, it is important to transparently track changes (e.g. ownership, refurbishment) to datasets. This can be achieved through blockchain technology, for instance, which has its main application in tracking financial flows (e.g. bitcoins). This aspect increasingly important (e.g. for verification) to ensure data validity when information from different databases is compiled. Information technology is indispensable when it comes to capturing, storing and analyzing dynamic information over long periods of time. Digitization is a central aspect when it comes to implementing materials passports and the circular economy in current building practice. Current and emerging technologies have seen a large jump in innovation in the previous years, but often their full potential is not always realized for all types of application. Digitization and the establishment of relevant standards (e.g. data formats) are key for a successful transition towards a circular economy.

4.2.2 Access via device

Building a circular system means redesigning the logic of industry, building a structure that is opposed to the linear one. This will involve some changes in the current job situation and new roles will appear. To allow this ever-increasing flow, there will be an increasing need for the contribution of everyone starting from the various countries, associations, companies, up to the final customer.

The passport must arrive updated at the right time to the right person, it is important to standardize the solutions where the machine that reads the format can hold and the software used. Also important is the correct format and language used by all. I imagined a strategy that has as its center the development of the materials database, with Material Passports acting as a user interface to filter relevant information for the reader.

The material database is the core of the circular process, which grows as the project evolves. There are otherwise some barriers that I highlighted in the process:

- **Cost**: it is cheaper to rebuild a product than to deconstruct an existing one and re-establish it

- **Design**: starting from different products to build one makes the process more complicated and materially difficult to build and time to do it

- **Risk**: how can we trust a new material built from existing ones, there is a lack of information on existing materials

Since the process must have a certain simplicity, it must be thought of an audience that can use it every day. Physical tags on the products components will consist of a QR code or RFID tag for active elements. When scanned, these will open the relevant record within the database. This allows the reader to filter information relevant to them, and also input new information such as maintenance or replacement notes.

Figure 9: QR code's tag use for MP

Thanks to any reader, such as a smartphone, we have the ability to access various information, as in figure 9. This information has a double function, and is divided into two macro categories:

- **Technical** - starting from the extraction of materials following certain standard data sheets (who supplies steel for example, chemical composition, technical property / s)
- **Environmental** - (energy required, quantity of equivalent CO_2 in the atmosphere, quantity of water consumed per process). Existence of sustainability assessment tools in the material passport is of a great importance (fig. 11).

Availability of such tools allows stakeholder to evaluate different products alternatives and compare them before buying them. Furthermore, they indicate the potential of using the elements for those who are interested in purchasing second hand components. Also, it can be used by authorities or environmental affairs to bring additional perspectives to green building and sustainability.

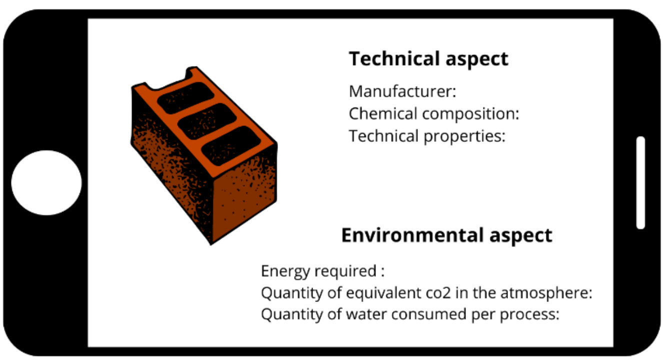

Figure 10: Material Passport's interface

This information has a dual purpose:

• Life cycle assessment (LCA), a methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service.

• Material conditions at the end of life (for best recovery scenario).

4.2.3 Data entry/updating

Once you have scanned the QR code you have two options (fig. 11), access the read-only sheet or transcribe the document with the key information (fig. 12).

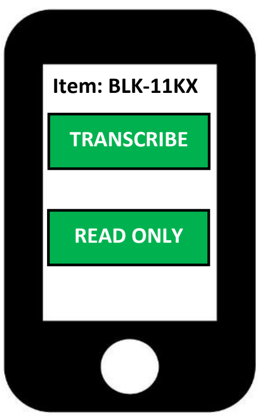

Figure 11: Material Passport's interface

To be able to transcribe the existing file you will need to have the necessary permissions given only to the companies that request it and that have respected some parameters, as in the photo below you will be prompted for the name of the company or reference body and the password to access.

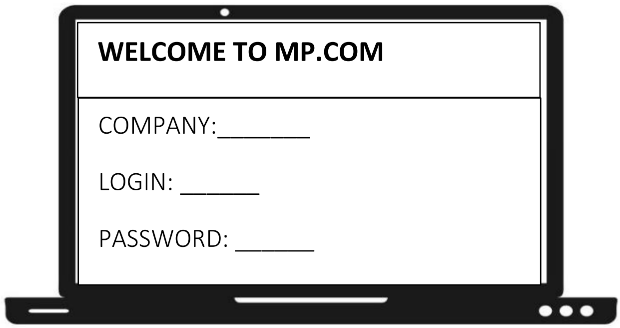

Figure 12: MP company's interface

As for the read-only file, just access the appropriate section, for this procedure it is important that it is easy to use and simple to understand. In this way we open to the use of a real database of materials which can be accessed via a QR code and a device. This process has huge implications because it allows you to see the recent and past history of a material. In this database it will also be possible to add other information such as:

- Unique identifier
- Name of the product
- Material
- Date of "birth"
- Manufacturer and place
- Others

Unique identifier	Manufacturer	Product name	Material	Components	Weight	Chemical composition	Date of birth	Origin	Energy required	CO2 emissions	Transport CO2 emissions	Water required	Recycled	Ricycle code	Phase
ASC01-RT23	JBF Industries Ltd	AP0076	PET	1	25 g	(C10H8O4)n	15/04/2022	India - Mumbai	2.1 MJ	58.2 g	\	\	No	1	Sourcing
ASC01-RT23	Società Generale delle Acque Minerali	AcquaLete PET 50 Cl	PET Plastic	1	25 g	(C10H8O4)n	01/06/2022	Italy - Pratella (CE)	0.24 MJ	22 g	62 g	1.5 l	No	1	Processing
ASC01-RT23	Montello S.p.A	\	Granular PET Plastic	1	25 g	(C10H8O4)n	01/10/2022	Italy - Turin	0.9 MJ	24.5 g	27.8 g	1 l	No	1	Recycling

Figure 13: Example of read only file

The information will be opened in a read-only file (fig. 13), to which the company owners of the object will have access in order to add, if necessary, a change to the product, without obviously affecting the previous one. A mechanism similar to the current blockchain, where information is interlocked in a chain - one after the other and there is no possibility of deleting it. This process lays the foundation for a whole new concept of a product purchase. We will have the opportunity to view history of a product and see the impact we have on our planet. The government and the European community will be able to keep track of every single product by putting rules that are objective and measurable by all. This register is linked to live commodity values, to give a real time and predicted future value of the materials in the project.

Furthermore, these platforms are best suited to projects utilizing ‘new’ materials, as it is set up for manufacturers to produce the Material Passports. In scenarios where these don’t exist, such as an existing material, the producer of the mentioned material will have to take charge of the drafting of the passport and this create a barrier to achievement. The role of the state or of the company that has the task of encouraging the process, even economically, comes into play.

The strategy has been developed to tackle the challenges associated with the existing approaches. I propose that the Material Passport is the user interface, rather than an input.

Instead of creating a platform which tags instances of a material in a model, the Material Passport is a record, reading a Material Database. This database has a bidirectional link to the excel during design, but can also be connected to Facilities Management software during future operation (Fig. 15).

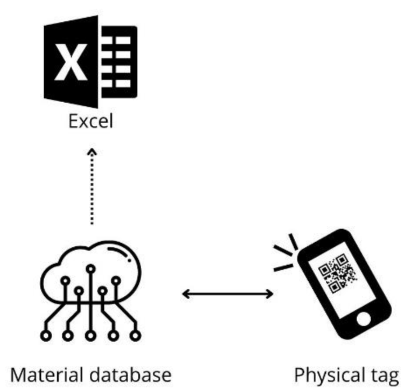

Figure 14: Comunication between the parties

Next step to develop the material passport:

1. Set up a Material Database, this could be the area that gives more opportunities, this would give greater control over the fields that are imported for each element category, and increase automation.

2. Connect it to the MP platform, this will improve functionality, allow for some automations and deliver an interactive Material Passport which can be accessed by scanning the physical tag.
3. Develop a Material Passport user interface, having the potential to unlock greater information sharing across a portfolio. Linking or consolidating Material Databases of projects will support future material reuse and insight into real time value of each Material Bank.

I realized how manual this process can be at the beginning, the goal is certainly to digitize and refine it gradually while maintaining the basic idea. The next step is to develop more sophisticated tools for the construction of the materials database and connecting into it.

4.3 BLOCKCHAIN

The possible implementation of the Material Passport calls attention to a tool that could be used for this particular function: the Blockchain.

Databases have the ability to store information in an electronic format. All people using the Material Passport have the ability to find inside exactly the product they are looking for. Databases are present in every business sector but not all are the same, some work through central authority or a permit, the Blockchain on the other hand works in different way. The information contained within it travels in blocks and can only be changed by adding a block to the chain.

The moment information is to be added to the database, a block is created that is added to the previous one without modifying it, just as it starts with the Material Passport. In this way there is the possibility of adding the information without altering the previous one, making it almost impossible to change it. For this reason, Blockchain technology is considered very secure.

An inherent feature of Blockchain technology is that it uses a peer-to-peer network. Each user within it gets a copy of the same Blockchain ledger, so there is no master copy, eliminating the need to trust a central authority and from the various hacking attempts. This is because if a hacker tried to modify the Blockchain he would only alter its copy.

In the case of a database such as the Material Passport database at least 51 percent, so more than half, of users would have to validate the wrong version of the. Blockchain for it to be considered valid. Considering the costs necessary for such employment and the use of resources having an error in the blockchain is virtually impossible.

5. CASE STUDY

5.1 INTRODUCTION TO THE PLASTIC MARKET

The material that I have decided to analyze in this path is plastic, a material that is very present in everyday life, just think that global consumption has increased 20 times in the last half of a century alone (Ellen MacArthur Foundation, 2020). The reason why they play such an important role is because they are able to adapt very well, they are flexible, water resistant and long lasting. This material hides some negative sides, in fact, the materials that recreate most of the waste in nature are plastic, considering that the production of this material involves a considerable use of fossil resources and energy, moreover there are risks for our health and for animals derived from microplastics and toxic additives.

Figure 15: Plastic waste, Ocean generation

To date, around 40% of plastic is used for packaging, many of which are disposable (PlasticsEurope 2019). It is also estimated that after the advent of COVID-19 there has been an increase in disposable plastic products of about 300% (The Economist, 2020). For analysts at the Ellen MacArthur Foundation, replacing as little as 20 percent of disposable plastic packaging with reusable alternatives offers a $ 10 billion savings opportunity.

The materials passport gives a 360 degrees knowledge of the use of products and ensures that plastics are handled responsibly during their life cycle, reducing the environmental impact. This is a theme that can no longer be hidden, in fact at present, about 500 organizations participate in the New Plastics Economy Global Commitment, in this way Unep and the Ellen MacArthur Foundation intend to lay the foundations of a circular economy for the reduction of plastic pollution and the protection of our oceans.

Four objectives have been formulated based on this common vision:

1. Anything that is not necessary and problematic for the environment must be eliminated.
2. Reuse plastic more after its first life cycle, reducing overall plastic consumption
3. Plastics are composted at the end of their life cycle through mechanical or chemical recycling. In the first case it is cleaned and melted into flakes or granules which will then become the basis for the subsequent products. Chemical recycling transforms polymers into monomers, these are used for the production of new plastics.
4. The incoming materials are safe, recyclable or renewable.

Having a circular economy, as we saw in chapter 1, allows for greater human and planetary well-being. The elimination of these four points is facilitated by the introduction of the material passport, in particular its introduction will help the process in several factors.

First of all, in the conscious use of resources, each section of the materials passport will report how much a product affects the environment, this should not be underestimated as at present a customer never has a clear conception of what he is consuming. Just think of when a food product did not print the macronutrients and calories contained on the label, it is now normal and many choices are based on that information because it is useful for understanding the type of product you want to buy. Using the information contained in the passport, it will then be possible to decide which products have less environmental impact or to choose a replacement.

Another factor to take into consideration is climate change, the elimination of plastic production would lead to a significant reduction in energy consumption and greenhouse gas emissions (4 tons of CO_2per ton of plastic according to The Pew Charitable Trust and Systemiq 2021).

In this case, the reduction of some materials can mean lower toxic emissions in the production process, in the specific case of this chapter plastic has serious repercussions on humans, animals and the environment. Eliminating plastic that would otherwise sink into the soil and marine environments would benefit both biodiversity and humans. This implies a huge cost in the tourism system in a few years, when for example, the failure to stop the production of plastic and therefore the emptying into the ocean will have important disadvantages for the tourism and fishing industries. Therefore, today producing plastic compared to other materials or continuing to produce new materials instead of recycling existing ones has lower costs only in the short term, because we do not consider the costs that there will be in the future to recover the situation that has worsened.

Evaluations indicate that the transition to a circular economy for plastics is not only an environmental necessity, but capable of bringing economic and social benefits. The parties who are interested across the company have acted. Several countries have put in place some bans to limit the use of plastic, some countries have issued tax breaks for manufacturers for recycling or the production of reusable products.

Consumers are increasingly aware of the social and environmental impact of their purchases. Accenture, a professional services company specializing in information technology (IT) services and consulting, estimates that globally, about half of consumers believe that providing information about its products, minimizing damage to the environment and investing in sustainability makes a most relevant and attractive company.

5.2 THE FOUR PHASES OF THE SUPPLY CHAIN (MATERIAL LIFECYCLE)

In order to best implement the Material Passport described in the previous chapter, a flow of information is required that covers the entire life of the material. To this end, current digital technology has all the features to allow the integration of data along the supply chain.

Since the life of a material is divided by different stages and also different actors it is important to know them in order to have the correct information from its extraction and production to its use. The phases that characterize the life of a material are the following:

- **Sourcing**: it is the phase in which raw materials are produced and extracted or secondary materials are used that want to be recycled.
- **Processing**: is the stage where materials are processed to have a finished product.
- **Usage**: it is the phase where the material performs the required functions, deteriorating over time.
- **Recovery**: it is the final stage, where the material ends its life cycle and a new one begins according to the possible strategies.

In the recovery phase, different scenarios can be created depending on the conditions of the materials, the Material Passport in this case plays a very important role because it allows us to have information and knowledge possessed by the stakeholders involved during the life cycle.

Such scenarios can be summarized in reuse, regeneration and recycling. Reuse is applicable when the product reaches the final stage in good condition and can perform its main function or in another value chain without significant restoration work. The regeneration, on the other hand, acts on the recovery of the materials used in the processing phase and the restoration of the initial conditions. Finally, the recycling of materials consists in the total disassembly of the product and each of its components to feed the procurement phase of the life cycle of materials as secondary raw materials.

As previously discussed, the lack of data and information along the life cycle of materials represents one of the main obstacles to the implementation of the circular economy. For this reason, in the last chapters a tool able to overcome this problem has been analyzed, the Materials Passport. In this chapter we will look at a practical example with the material we analyzed earlier. This system will have the ability to improve traceability along the value chain and stimulate the development of circular products.

5.3 PRACTICAL PATTERN

I decided to consider for this chapter a material that has a very strong global and environmental impact, as seen in the first part of this section. This certainly has a strong application in everyday life, and is used by a large part of the population. In this part of the chapter we are going to look at the journey of a plastic bottle from the sourcing stage to the recovery stage.

The life cycle of plastic changes depending on the type of product you are dealing with. However, it is possible to draw general lines that may involve either the birth of one of the most long-lived and resistant materials in the world, or its death or, at best, its rebirth. Let's see together his path through this world of plastic.

The battle against plastic involves a serious problem. In fact, the excessive presence of this material on the Planet, has to do not only with its quantity, but also and especially with the length of its life cycle. In fact, plastic is in no way biodegradable. As a result, it is virtually impossible that at some point in its life cycle it will simply revert to its initial stage. As one of the materials that most represents the human footprint in the world, plastic is durable, long-lived, almost indestructible. It does not melt, it does not pulverize, it does not erode.

5.3.1 Sourcing

Sourcing is a process that requires different actors in the supply chain at different stages of a product's life. The first stage we consider is sourcing. Materials at this stage are most often in raw form and need to be arranged to create a finished product.

Plastic is a polymer, which is a collection of molecules joined together, and is made by the extraction of oil or other fossil fuels. Once the raw material is extracted, it undergoes a refining process, which is called cracking, this process is used to split chains of molecules by extracting smaller ones, thus having monomers.

At that point, through a process called polymerization, the monomers that make up the plastic bind together to become polymers, thus plastic is born. Of course, all plastic is not the same. The same polymerization processes can occur in different ways, and the products that result from these processes are different.

The use of Polyethylene terephthalate (PET) is growing year after year, it is mainly used for packaging, especially for beverage bottles. The increase in PET production has increased in the EU alone from 1.9 to 2.9 million tons between 2001 and 2008, reaching a global value of 73 million tons in 2020. As for plastic bottles, there has been a 100%

increase in the last 8 years and the figures do not seem to be decreasing (The Guardian et al.)

With this data in hand, it is important to track all of its components through the material passport so that it can be reused in the best possible way.

This first process is important because it includes such a critical step as extraction.

In the case we are considering of the plastic bottle, the company that is going to resell the raw product will have to provide the necessary information to the company that will finish the process of producing the plastic bottle. This process takes place in two ways:

- Virgin PET manufacture
- Secondary productions

In the first case involving virgin product, material extraction will be required involving more energy in extraction and new material to be used, 28.8 g to make up a 1.5L bottle to be exact. (Shell et al.) In our example one-third of the polyethylene terephthalate mentioned above will be used which will allow us to have a finished product like a small bottle.

In the case in example, the material that has the characteristics represented in table 5 is produced by JBF Industries Ltd and then sent to Italy along with the product information in question.

Table 3: AP 0076 product information for packaged water applications

Analysis	UTM	Unit	Typical Value
Intrinsic Viscosity	ASTM D 4603	dl / g	0.76 ± 0.02
Carboxyl End Groups	Titration	meq / kg.	30 max
Acetaldehyde	GC	ppm	< 1.0
Color L	Hunter scale	---	> 80.0
b			< 1.50
Melting Point	DSC	°C	246.5 ± 2.0
Crystallinity	Density gradient Column	%	> 50
Chips Per Grams	Physical	Number	65 ± 5
Dust Content	Sieving	ppm	< 100
Moisture	Vapor Pressure Apparatus	%	< 0.1

The second possibility starts with the recycling of plastic that has already been used for other purposes. The treatment required to bring the bottle back to a second life is done through the Solid State Polycondensation process. This process creates a new model resulting in an energy expenditure of 1.96 MJ/kg (Shen et al).

The supplier collects information related to the extraction or reuse of plastic material and sends it to the plastic bottle manufacturer who will be responsible for finalizing the information and applying it within the material passport. From this point forward, the plastics born from the various processes are sent to the various industries and then begin their life within the market in the form of everyday objects, as in our example of the plastic bottle.

5.3.2 Processing

In the case under consideration of the plastic bottle, in particular this example is based on the company Acqua Lete and following all stages of its production process. In this case, the manufacturing company handles processing phase by going through the following functions:

1. **Start-up**. The start-up of the production process takes place in the press department, where PET (polyethylene terephthalate) granules are dried, brought to a temperature of about 300° C and mixed with the master, which gives them the desired coloring.

The PET is then injected into multiple molds that produce thousands of preforms (semi-finished products) per hour, from which, by blow molding, the bottles are made (fig. 16).

Figure 16: PET multiple molds, Plastic technology

2. **Bottle**. The resulting preforms are sent to blow molding machines that heat them in infrared furnaces to temperatures above 100° C and introduce them into molds. Here the preforms are blown with high-pressure air jets to make them take on the shape of a bottle (Fig. 17).

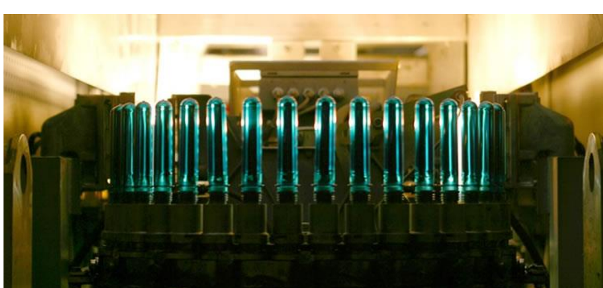

Figure 17: Bottle preforms, Plastic technology

3. **Filling**. In the sterilizer, the bottles are further sanitized and rinsed. In the filling machine, the bottles are filled and sent to the capsulator, where they are immediately capped with capsules complete with the guarantee seal. The filled and corked bottles arrive at the labeling machine, which emblazons them with a wrap-around body label; the bottles then undergo laser label marking indicating the production lot and minimum shelf life. At this stage, a QR code is printed in the label that will enable people to be able to read and edit the Materials Passport.

4. **Confectioning**. In the final packaging process, the bottles, having arrived at the packaging machine, are divided into blocks and then wrapped in film with heat-shrink properties, thus forming the bundle. The bundles are then ready to receive the handle on which the minimum shelf life of the packaged product is affixed.

5. **Packing**. The bundles are sent to the palletizers whose task is to arrange them appropriately in overlapping layers with cardboard interlayers in between, according to precise patterns, so that they can be wrapped and protected by film with stretchable properties, giving the pallet the solidity and stability

necessary for storage and transport on vehicles. In addition, wrapping the pallet with stretch film provides an important barrier effect to external agents.

This company is then responsible for receiving information from the first supplier and starting the production process. We can divide the steps into:

- Information gathering
- Sharing information

Figure 18: AcquaLete PET 50 Cl, AcquaLete

The first part that a company should take care of to implement a circular system is the collection of information about a material. In this specific case we are going to look at the example of a 0.5 liter plastic bottle (Fig. 19).

Every water bottle company knows perfectly the materials that make it up for each size of the bottle and the process will have to carry out to make polyethylene terephthalate a finished product. In this example we are treating the plastic material as virgin, but we know that material suppliers can introduce already recycle material.

The information the company collects on a finished product must be entered into the reference platform, remember that only companies have access to the ability to add a new product via company name, login and password that allows the site to recognize who is entering the information as in fig.20. Once in the database, the system requests information about the end product and assigns a unique code to the product.

Figure 19: MP's platform

Once the information is entered correctly a QR code will be given as output that can be affixed directly to the product. This QR will allow the entered code to be changed or the information entered within it to be read.

This is one more job to do for a company that for years and years has only thought about selling products without worrying about where they would end up after the sales phase so the role of government will be important.

Governments can lead the transition to a circular economy for plastics by creating a business environment in which negative externalities are internalized, thus aligning economic incentives with positive environmental and social outcomes. This can be done by setting balanced targets for the transition, providing policy incentives for the adoption of circular design, reuse, recycling, and data tracking.

The second part that a company should take care of to implement the circular system is sharing the information gained in part one (information gathering). I have identified a time when it would be easiest to do this with regard to plastic bottles, which is the filling stage, but each company has its own routines and it is only fair that they can organize accordingly. In any case, sharing this information should be easy to extract. In the recommended model, a QR code capable of being quickly scanned and easy to read is used.

At the time of recording the information of the materials that will form a product an identifying QR will be shared by the system, capable of giving information from this moment forward. It is important to note that each product has its own identification code and cannot be grouped together because from there on there are so many variables that could take that bottle from one part of the hemisphere to another.

The shared data will be made public to all and some of it used only in some specific cases. However, it is important that the key information described earlier is easy for the end customer to read. In this way the user will be able to understand the environmental impact his or her purchase has in the world and can guide decisions in this regard, preferring or not preferring a product.

There will be the introduction of a new parameter in purchasing: environmental impact. In this way, every company will have as one of its main goals the use of products with a low environmental impact and not only the economic aspect, giving enormous transparency in the extraction of material and its production and developing metrics to measure impact and progress. A company will then need to be able to understand behavior and change management. Develop effective strategies for both consumer behavior and organizational change.

It is conceivable that new workers capable of acting as material passport and environmental impact reduction consultants will be introduced into the workforce. Without considering new workers in the control of information entry with the ability to be able to intervene if the process does not happen correctly.

5.3.3 Usage

Once the important role of the product company has been clarified and the data have been entered correctly, every customer has the opportunity to view them before the use phase. This is an argument that can be made for first use or second use. If we wanted to buy or sell a product we have the record of its recent and past history just a click away. Considering that the data-entry system is based on the concept of blockchain and therefore we do not have the ability to delete the passes it has made. The security is that the material passport is a 100 percent reliable tool, thanks to which I have all the information about the product in real time.

Imagine you are at the supermarket and you are basing your decision on a recycled product or a new one. You have the option of framing the QR encoder on the plastic bottle in the shelf as in fig. 21. You are about to choose the plastic bottle and you frame the QR code to understand the environmental impact your purchase may have and deepen your understanding of the environmental and socioeconomic impacts of different types of bio-based plastics. It is a completely new process that can introduce new purchasing choices and thus purchasing habits.


Figure 20: QR code on the plastic bottle, 12RF

The information that a customer can have was told in the previous chapter, in the table 5 we can have the information of the plastic bottle in this practical example. Upon purchase, via QR the product is assigned to a customer where it can begin a life of its own and perform the function for which it was originally designed.

5.3.4 Recovery information

Once the life span of the plastic bottle is over, there are three viable paths: being incinerated, ending up in a landfill, or being recycled.

When we talk about plastic bottles the incinerator is almost never a good idea. Although it can bring a good amount of energy gained it releases substances with the melting that are harmful to people and the environment.

The second option is unfortunately not viable in the same way because plastic is not biodegradable, which means it will be in the environment for hundreds if not thousands of years after the end of its use. This material while not degradable is recyclable, the best prospect is for the plastic bottle to be reused, either to bring the same product to life or for a different purpose.

The plastic recycling process takes place in special plants, which are responsible for turning the bottle in question into flakes and granules, which will be melted and fed back into molding plants.

Not all plastics can be equally recycled. It depends not only on the characteristics but also on the additives contained in the plastics. In addition, the recycling process is divided into several steps, one of the most important and time-consuming being the collection and division of the various plastic products.

The plastic bottle has debased its main activity, moving from one actor in the supply chain to another, retaining with it the information that distinguished it from other products. Right now, this data can be useful in understanding the product's life status and verifying its recyclability.

There is some information that can be helpful in facing the recycling process in a simpler way. The plastic recycling process is divided into several parts, and separating the initial collection of different plastics greatly reduces the complexity of the process, leading to higher output qualities (fig. 22).

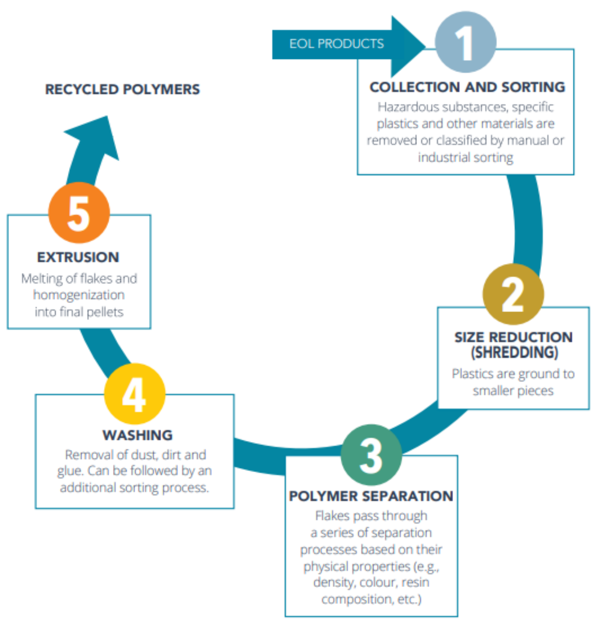

Figure 21: Plastic recycling process, Plastic Recycling Factsheet, Euric AISBL

The different materials into which the process is divided before further division into size is carried out thanks to the Material Passport, which will give information regarding the type of plastic material. Specifically:

1. POLYETHYLENE TEREPHTALATE (PET)

• PET is a dimensionally stable thermoplastic with excellent machining characteristics. It is clear, tough and solvent resistant. Commonly present in: beverage bottles, microwavable trays, and

• PET items are highly recyclable; however, proper collection is instrumental to avoid cross-contamination from other materials (e.g., colorants).

2. HIGH-DENSITY POLYETHYLENE (HDPE)

• HDPE is a versatile, high-impact, lightweight thermoplastic with an excellent chemical resistance and high tensile strength. Commonly present in: milk and detergent bottles, plastic bags, toys, pipes and furniture.

• Although HDPE is highly recyclable, only 10-15% is recycled in Europe as, due to its softness, it needs to be sorted from harder fractions of plastics before treatment.

3. VINYL/POLYVINYL CHLORIDE (V/PVC)

• High corrosion resistant plastic, hard, rigid, can be clear, can be solvent welded. Commonly present in: blister pack/clamshell packaging, shampoo bottles, meat packaging, cables, inflatable pools and window frames.

• Easy to separate by conventional processes, however recycling is limited due to the presence of some additives (e.g., chlorine, cadmium, lead).

4. LOW-DENSITY POLYETHYLENE (LDPE)

• Soft flexible plastic with excellent abrasion, chemical and impact resistance. Commonly present in: squeezable bottles, shrink wrap, bread bags, frozen food bags, wire and cable applications.

• Generally recyclable however, due to its softness, it needs to be previously sorted from harder fractions of plastics and treated in adequate recycling processes.

5. POLYPROPYLENE (PP)

• It is an economical, lightweight thermoplastic that offers high corrosion, abrasion and impact resistance. Commonly present in:

yogurt and margarine containers, bottle caps, ketchup bottles, food packaging, reusable containers and plant pots.

• PP items are highly recyclable; however, recycling is limited due to difficulties in collection, contamination and mixture with other materials (e.g., colorants).

6. POLYSTYRENE (PS) AND EXPANDED POLYSTYRENE (EPS)

• While PS is clear, glassy, rigid, brittle, opaque and melts at 95°C, EPS is foamed, lightweight, energy absorbing and heat insulating. Commonly present in: meat/poultry trays, plastic foam cups/plates, CD cases, plastic cutlery, eyeglasses frames, video and CD cases, and egg boxes.

• Generally recyclable, however its low density makes it difficult to process through conventional recycling processes.

7. MISCELLANEOUS PLASTICS

• Other plastics such as bioplastics or plastics formed by a combination of resins or multi materials of unknown composition (e.g., oven baking bags, some reusable water bottles, plastics for automotive, aircraft, medical parts, etc.).

• Rarely recycled as they are not compatible with conventional recycling processes due to the variability of its properties. (PlasticsEurope Deutschland e. V. and Messe Düsseldorf.).

These various types of plastics (Fig. 23) have a code that allows them to be recognized and therefore recycled. This code along with other information is present in the Material Passport. Besides the codes that represent the plastic products there are: paper, metal, textile materials, wood, glass and compounds. So, by reading the Materials Passport we will have a clear idea of the material we have in front of us and its chemical composition.

Figure 22: Plastic recycling code, green living tips

The Material Passport will make it possible to know everything about the product in question. Through the product scan, they can be co-invaded into one conveyor for the particular type of plastic or another. This process gives the ability to be able to sort the various products more quickly and efficiently by facilitating phase one of the recycling process called collection and sorting. The digital information allows us to know where a product originated and understand how it can be recycled. In this practical example, reading the information allows us to figure out what direction to take. We have analyzed a single product but try to imagine having a decomposable product in front of you and with its material passport being able to have all the useful information on how to break it down so it can be recycled.

5.3.4 Restart of cycle production

Recycling plastics allows the cycle to close by giving the opportunity to start a second one, reintroducing into production the waste from the first cycle that is transformed into a resource, bringing the following benefits:

- Increased recycling rates
- Stable markets
- Controlled exports
- Reduction in CO_2 emissions and water consumption

- Decreased use of natural resources

Once the cycle is complete, the Material Passport allows you to have the information needed to be able to recycle a given product. In the example we considered, the final product is a recycled Ferrarelle S.p.A. bottle of 100 Cl (Fig.24). This product is the result of two different products (Table 5; Table 6).

Figure 24: Ferrarelle, Acqua Minerale Cl100, Ferrarelle 2022

As part of the production of plastic materials, and particularly mineral water bottles, the use of recycled Pet must comply with certain constraints imposed by Ministerial Decree No. 113 of 2010:

- Recycled Pet for the production of plastic bottles, as in our example, must be accompanied by a certification that the finished object complies with Article 3 of Regulation (EC) No. 1935/2004.
- Recycled Pet comes from the recycling of food-grade Pet bottles.
- The bottles must contain at least 50 percent virgin Pet, thus never used, and can only come in contact with natural mineral water.

It follows that recycled Pet used for plastic bottle must mandatorily follow processes that ensure its safety and sanitary suitability, the Material Passport can certainly help in checking these metrics. According to this legislation then, the maximum limit of R-pet that can be used for mineral water bottles is 50 percent. Used plastic bottles can be recycled once cleaned in the recovery process. This process saves raw materials and energy lost to the environment. If we recycle a plastic bottle how much recycling energy will we use compared to the energy of a virgin product?

PET recycling uses 35 MJ/kg of energy and CO_2 emissions are 0.98 kg CO_2 per kg of material (Table 7). The embodied energy as we have seen is 84 MJ/kg, recycling therefore saves 60% of the energy needed to supply PET for future products (Ashby MF, 2009).

In terms of CO_2 emissions, the difference for virgin and reused PET is about 1.35 kg CO_2 /kg (2.33 - 0. 98). For a 50 g bottle, as in example, recycling potentially saves emissions of 0.05 x 1.35 = 0.067 kg CO_2. This represents only 0.25% of a person's daily carbon footprint (30 kg CO_2), so recycling 400 small bottles will make a person emission-neutral for one day. It sounds like a lot, but it is a routine that can be implemented day after day (Ashby MF, 2009).

An important, and often overlooked, role is played by transportation. In fact, a good portion of emissions come from this factor, especially if, in order to get a cheaper product, people shop in countries where it is convenient to produce, such as India. In this practical example, transportation covers 43 percent of total emissions. If virgin pet was mined and produced entirely in Italy, on the other hand, it would be only 30 percent, a symptom of how many companies think about net profit and little about the environment.

It is important to note the role of the Material Passport in reusing certain materials such as plastics. For this example alone, tangible results are important in going after the circular economy. However, there are intangible results that are difficult to put under the magnifying glass but no less important for that reason. Just think of the new way of decision making and information gathering for companies and customers, the ability to have widespread control over where products arrive and how they are sourced, and the production methodology. This has the potential to trigger a mechanism by which the work of each individual company is visible and can make a difference.

Table 5: Material Passport's layout

Unique identifier	Manufacturer	Product name	Material	Components	Weight	Chemical composition	Date of birth	Origin	Energy required	CO2 emissions	Transport CO2 emissions	Water required	Recycled	Ricycle code	Phase
ASC01-RT23	JBF Industries Ltd	AP0076	PET	1	25 g	(C10H8O4)n	15/04/2022	India - Mumbai	2.1 MJ	58.2 g	\	\	No	1	Sourcing
ASC01-RT23	Società Generale delle Acque Minerali	AcquaLete PET 50 Cl	PET Plastic	1	25 g	(C10H8O4)n	01/06/2022	Italy - Pratella (CE)	0.24 MJ	22 g	62 g	1.5 l	No	1	Processing
ASC01-RT23	Montello S.p.A	\	Granular PET Plastic	1	25 g	(C10H8O4)n	01/10/2022	Italy - Turin	0.9 MJ	24.5 g	27.8 g	1 l	No	1	Recycling

Table 6: Second plastic bottle MP's layout

Unique identifier	Manufacturer	Product name	Material	Components	Weight	Chemical composition	Date of birth	Origin	Energy required	CO2 emissions	Transport CO2 emissions	Water required	Recycled	Ricycle code	Phase
ASC12-RT54	JBF Industries Ltd	AP0076	PET	1	25 g	(C10H8O4)n	10/02/2022	India - Mumbai	2.1 MJ	58.2 g	\	\	No	1	Sourcing
ASC12-RT54	Acqua di Nepi S.p.A	San Benedetto PET 50 Cl	PET Plastic	1	25 g	(C10H8O4)n	14/05/2022	Italy - Scorzè (VE)	0.26 MJ	22 g	62 g	1.5 l	No	1	Processing
ASC12-RT54	Coripet S.p.A	\	Granular PET Plastic	1	25 g	(C10H8O4)n	01/10/2022	Italy - Milan	0,9 MJ	24.5 g	9 g	1 l	No	1	Recycling

Table 7: Result of reciclyng MP's layout

Unique identifier	Manufacturer	Product name	Material	Components	Weight	Chemical composition	Date of birth	Origin	Energy required	CO2 emissions	Transport CO2 emissions	Water required	Recycled	Ricycle code	Phase
Material recicled thanks to Materialpassport.com, products used: ASC01-RT23; ASC12-RT54															
ASC01-RT23	Montello S.p.A	\	R-PET	1	25 g	(C10H8O4)n	01/10/2022	Italy - Turin	0.45 MJ	12 g	\	1 l	Yes	1	Sourcing
ASC12-RT54	Coripet S.p.A	\	R-PET	1	25 g	(C10H8O4)n	01/10/2022	Italy -Milan	0,45 MJ	12 g	\	1 l	Yes	1	Sourcing
BQC10-PS03	JBF Industries Ltd	AP0076	PET	1	25 g	(C10H8O4)n	12/04/2022	India - Mumbai	2.1 MJ	58.2 g	\	\	No	1	Sourcing
BQC10-PS03	Ferrarelle S.p.A.	Ferrarelle RPET 100 Cl	R-PET Plastic	1	50 g	(C10H8O4)n	14/05/2022	Italy - Riardo (NA)	0.48 MJ	43 g	87 g	3 l	Yes	1	Processing
BQC10-PS03	Coripet S.p.A	\	Granular R-PET Plastic	1	50 g	(C10H8O4)n	01/10/2022	Italy - Milan	1.2 MJ	47 g	47 g	2 l	Yes	1	Recycling

Table 8: Corelation between products

Final product	Origin product	% Used	Recycled
BQC10-PS03	ASC12-RT54	25%	Yes
BQC10-PS03	ASC01-RT23	25%	Yes
BQC10-PS03	BQC10-PS03	50%	No

Of the entire PET family, bottle recycling has the most developed technology and infrastructure. Across Europe, collection schemes for PET bottles vary. Some countries are achieving high recycling rates with beverage deposit refund schemes (DRS), while other countries and regions are achieving lower recycling rates with separate collection schemes.

According to Zero Waste Europe and Eunomia Research & Consulting PET bottles have a Recycling Rate of around 50% (calculated using the weight of PET material at the stage after wash and flake vs the weight of PET bottles).

There is no standardized collection and sorting of non-bottle PET applications in Europe. For this reason, a tool that can help the process of sorting plastics is useful, so as to elevate the low percentage of recycled plastics.

A future scenario will likely see bottles being managed in a much more circular way than currently is the case.

5.4 CONCLUSION

The Material Passport is critical to the necessary transformation in the way plastics are produced, used, and processed at the end of their use. As we have seen in this chapter in a circular economy for plastics, in particular, problematic or unnecessary plastics are eliminated; material inputs for plastics are safe, recycled, or renewable; plastics are reused more; and plastics are recycled or composted at the end of use. Circularity is not the ultimate goal, but rather an important means of getting there, a comprehensive economic system that enables human and environmental well-being. A circular economy for plastics can have profound effects on resource use, climate change, human health, biodiversity, and economic well-being. Let us be guided by the digitization of the process, set balanced goals that are crucial to designing the transition, monitoring progress, and assessing impact. The transition path to circularity is challenged by barriers, many beyond the control of each individual supply chain stakeholder. Governments, businesses, civil society, financial institutions, and research organizations all together have a major impact. Each of us has a role to play, and there are specific actions we can already take today. Let's take responsibility and do what we can to drive change. It's time to start using tools like the Material Passport, mapping progress, co-creating actions, building new partnerships, demonstrating best practices, sharing learnings, and driving new engagements throughout the year and beyond to drive large-scale plastics system change.

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