Sustainable future in the payment cards industry: Eco-innovation

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Content

Introduction

From gold coins to cryptocurrencies, the landscape of payment methods help shape the way societies are organised and how communities relate. Plastic payment cards are established nowadays as the most trustworthy, popular and practical means of payment. Users can enjoy the convenience of paying for any amount virtually anywhere with one reusable card, instead of paper or coin forms of money, whilst being protected by increasingly improving security measures against fraud and theft.

Meanwhile, the global climate crisis is reaching its climax, with plastic pollution as one of its main catalysers. Plastic credit cards are difficult to recycle (1) and are typically made from materials which are harmful for ecosystems. Most bank cards are composed of PVC, a plastic material that when incinerated under nonideal conditions can release toxic substances and when disposed of in landfills, pollute groundwater. Moreover, around 8 million tonnes of plastic end up disposed of into the ocean each year, according to the nonprofit environmental group Plastic Oceans (2).

Alternative materials and recycling techniques are available to improve the environmental impact caused by payment cards. This paper aims to give context on the history of plastics and its use in the landscape of payments, to describe more conscious and implementable choices for the card body material of payment cards, and to advise on the approach to the end of life cycle of those cards, considering environmental, social and economic impacts.

Banks, their role in society and sustainability

Banks are financial institutions licensed to receive deposits and make loans to private and corporate clients. They might also provide financial services such as wealth management, currency exchange and safe deposit boxes. Banks provide society with financial resources and are often the platform used for vital transactions for consumers, businesses and governments.
In return to being a safe place to store cash, banks are collections of investment capital in search of a profitable return. They do this by charging more interest on loans and other debt issued to borrowers, then paying interest to customers who use their savings vehicles (3).

During the global financial crisis that peaked in 2007 and 2008, banks came under intense scrutiny. The worst economic disaster since the Wall Street Crash of 1929 started with a subprime mortgage lending crisis, which was followed by a global banking crisis. As a result of that, general trust in Banks declined severely, and the regulatory environments for banks have tightened considerably in order to avoid such future crises. With more regular audits and inspections, regulatory agencies now have higher control on permitted practices and on the amount of interest banks are allowed to charge consumers with.

When considering the staggering amount of money managed by banks and the impact this management has on all industries, the influence of those financial institutions on the economy and society becomes more apparent.

Banks have a systemic impact in the economy: they are essential to the financing of business and individuals. Banks hold decision power as to where money is invested and so they enable a big share of the social-environmental impact of businesses. Banks have a gatekeeper role on society's sustainable practices. By defining and evaluating financial and non-financial risk scenarios, looking forward to a future self-resilient society, these institutions have the potential to play a vital role in countering climate change and social-economic issues.

Sustainability is the capacity to sustain, to maintain something at a desired stable level. In the context of financial growth, sustainability means the ability to keep the growth rate of, for example, a company's revenue stable. This is a concept fundamentally connected to capitalist systems that aim to increase consumption of goods and services while providing jobs and fair wages to workers, and profits to company owners. The sustainability of that system is maintained through the balance between the money generated (wages and profits of the delivery of goods and services) and the reinsertion of that money in the market, as workers and company owners increasingly gain buying power provenient from sales of products and services.

Regarding the natural environment, the concept of sustainability is linked to the capacity of ecosystems to thrive. During 1987's (4). United Nations' Brundtland Commission, sustainability was defined as 'meeting the needs of the present without compromising the ability of future generations to meet their own needs', implying limits imposed by the present state of technology and social organisation on environmental resources, and by the ability of the biosphere to absorb the effects of human activity (5).

In 2015, the 2030 Agenda for Sustainable Development (6) was launched as a 15-year plan to achieve the 17 Sustainable Development Goals (SDGs). The goals are a universal call to action to end poverty, protect the planet and improve the lives and prospects of everyone, everywhere (7).

In 2019, world leaders at the SDG Summit (8) called for a Decade of Action (9) and delivery for sustainable development, and pledged to mobilise financing, enhance national implementation and strengthen institutions to achieve the goals by the target date of 2030.

Considering the impact of financing on economic growth and on the environment, the regulatory agencies and NGOs urge private and public sectors to focus on sustainable financing. Sustainable financing refers to the process of taking environmental, social and governance (ESG) considerations into account when making investment decisions in the financial sector, leading to more long-term investments in sustainable economic activities and projects. Environmental considerations might include climate change mitigation and adaptation, as well as the environment more broadly, for instance the preservation of biodiversity, pollution prevention and the circular economy. Social considerations could refer to issues of inequality, inclusiveness, labour relations, investment in human capital and communities, as well as human rights issues. The governance of public and private institutions – including management structures, employee relations and executive remuneration – plays a fundamental role in ensuring the inclusion of social and environmental considerations in the decision-making process.
In the EU's policy context, sustainable finance is understood as finance to support economic growth while reducing pressures on the environment and taking into account social and governance aspects. Sustainable finance also encompasses transparency when it comes to risks related to ESG factors that may have an impact on the financial system, and the mitigation of such risks through the appropriate governance of financial and corporate actors (10).

Sustainable financing, as well as an environmentally sustainable approach on business and governance, are crucial for ensuring that both needs of current and future generations are not compromised.
The financial services industry is making a concerted effort to adopt better sustainability practices. In 2019, the ‘Principles for Responsible Banking’ (11) were created through a partnership between founding banks and the United Nations. These principles are designed to bring purpose, vision and ambition to sustainable finance. Signatory banks commit to embedding these 6 principles across all business areas, at the strategic, portfolio and transactional levels.

Principles for Responsible Banking

By the United Nations & over 250 signatory banks, representing over 40% of banking assets worldwide.

Principle 1: Alignment
We will align our business strategy to be consistent with and contribute to individuals’ needs and society’s goals, as expressed in the Sustainable Development Goals, the Paris Climate Agreement and relevant national and regional frameworks.

Principle 2: Impact & target setting
We will continuously increase our positive impacts while reducing the negative impacts on, and managing the risks to, people ena environment resulting from our activities, products and services. To this end, we will set and publish targets where we can have the most significant impacts.

Principle 3: Clients & customers
We will work responsibly with our clients and our customers to encourage sustainable practices and enable economic activities that create shared prosperity for current and future generations.

Principle 4: Stakeholders
We will proactively and responsibly consult, engage and partner with relevant stakeholders to achieve society’s goals.

Principle 5: Governance & culture
We will implement our commitment to these principles through effective governance and a culture of responsible banking.

Principle 6: Transparency & accountability
We will periodically review our individual and collective implementation of these Principles and be transparent about and accountable for our positive and negative impacts and our contribution to society's goals.

In order to implement the commitment to the 6 principles, signatory banks follow a 3-step process:

1. **Impact analysis:** Identifying the most significant impacts of products and services on the societies, economies and environments that the bank operates in (12).

2. **Target setting:** Setting and achieving measurable targets in a bank's areas of most significant impact (13).

3. **Reporting:** Publicly report on progress on implementing the Principles, being transparent about impacts and contributions (14).

Through those Principles, banks are convened by the United Nations to collectively produce cutting-edge guidance and pioneering tools on key areas of sustainable finance, learn best-practice from their peers, scientists and industry experts, and benefit from individual feedback and collective reviews as they progress on their sustainability journey.

The environmental footprint of banks

Most of the impact banks have on social and environmental issues is created through relationships with clients and customers, via loans and investments, but part of the implementation of the Responsible Banking Principles lies on banks' own operations (15). With such a fundamental role in society, banks are starting to help lead the global transition to a low-carbon, climate-resilient economy. It is relevant for banks to transform themselves into exemplary institutions that encourage and enable customers and clients to transform their own habits and lifestyles into more sustainable ones. This starts by managing the banks' environmental footprint through their own operations.

The environmental footprint (16) of the operations of a bank can be divided into:

- Energy use
    - This includes the energy consumed by office buildings, customers and data centres. In order to understand and optimise energy use, regular monitoring, reporting

and reduction strategies should be carried out, while the use of renewable energy should be preferred.

- Business travel
  - An increased use of technology, such as video conferencing, can optimise digital collaboration between employees and suppliers in different locations, limiting unnecessary travel. When travelling is necessary, employees can best opt for public transport and electric vehicles, and avoid air travel when possible.
- Water usage
  - The water footprint of a bank is usually low when compared to other industries with physical products, but in office buildings and customer centres water usage can become more efficient with rainwater collection systems for sanitation, aerators for faucets, and updated appliances.
- Procurement
  - When choosing to hire a supplier, financial efficiency and quality of service are traditionally the biggest points of consideration. For social and environmental responsibility, potential suppliers should also be evaluated based on the UN Global Compact Principles (17), which comprehend topics of anti-corruption, environment, labour and human rights.
- Waste
  - Regarding the conservation of natural resources, the waste areas of concern for a bank are paper, general waste and plastics.
    - The two first kinds of waste can be reduced by greater use of digital media, eco-labelled paper, efficient printing, recycling and e-waste management.
    - The use of single-use plastics in banks can be mostly avoided by eliminating the material from catering services. The remaining waste of plastics regards the production and distribution of payment cards. Plastic cards must follow specific production standards and acquire certifications dependent on card payment schemes (i.e. Visa and Mastercard). Traditionally, payment cards have been certified for production on first-use PVC, but after the launch of the 2030 Agenda for Sustainable Development, card producers, payment schemes and card issuers (banks) have

worked together to develop implementable material alternatives to payment cards.

Remaining carbon emissions are usually compensated by the purchasing of voluntary carbon units. These units are equivalent to, for example, the preservation of rainforests, reforestation of natural reserves, agricultural training in local communities, or other activities that promote sustainable development related to lowering the impact caused by human caused carbon emissions.

When taking initiatives for improving the social and environmental impact of companies, it is relevant to not only understand and improve the impacts of the company's products, but also to constantly monitor and manage if such initiatives are still relevant and valid.

In August of 2021, a group of law students of the Free University of Amsterdam made a complaint (18) to the Netherlands' advertising Code Committee against the oil and gas company Royal Dutch Shell. The complaint urged Shell to stop promoting an advertising campaign that claimed that those buying Shell's petrol and diesel can choose to pay an extra cent of euro per litre to fund the carbon neutrality of the fossil fuels purchased. The ad campaign 'Drive CO2 Neutral' implies that the extra fee is enough to compensate for the carbon emissions of the fuel purchased. The information shared with the public is claimed to be misleading as Shell could not prove the full offsetting of the emissions. Greenwashing cases such as this can lead to mistrust towards the public and hinder the execution of the 2030 Agenda for Sustainable Development. As a consequence of greenwashing and misleading environmental marketing campaigns, the public is kept in the dark of the consequences of their purchase habits, while companies are less pressured to follow up on compromises leading to mitigate the effects of climate change.

While carbon offsetting initiatives can help slow down the delta of emissions during the transition to a carbon neutral society, this system should not be regarded as a permanent solution to the transition of companies towards carbon neutrality and sustainability. In the banking sector, optimal transition happens when a bank not only supports greener companies, but also, and maybe more importantly, when they stop providing loans and investments towards companies that provide less contribution to a sustainable future.

By holding environmentally conscious loan and investment portfolios, by reducing the footprint on own operations, and by monitoring and openly reporting progress, banks can engage on a promising and transparent path towards sustainability.

The following chapters will expand on the footprint reduction of the own operations of banks, specifically focused on plastic payment cards. As mentioned earlier in this chapter, eco-innovative solutions for payment cards materials are available for production. When implemented in parallel to other sustainability focused initiatives, eco-cards can enhance not only the brand image of a bank towards customers and enable them to take responsibility for their own sustainable habits, but also genuinely support the transition to a greener company and society.

History of plastic use and production, and the problem of plastics

Plastic origin and its production processes

Plastics, polymers, are organic or semi-organic materials with a high molecular weight. They are composed of interconnected macromolecules, from which the combinations of molecule connections will establish the polymer's properties.
They can consist of pure polymers or, in most cases, be the result of a mix of polymers, additives and fillers. The most common polymers are of essentially synthetic origin (derived from petroleum), but there are also plastics which derive from renewable resources.
Plastics have advantageous properties when compared to other material families in regards to their great ease of processing, cost-effectiveness, colorability, their acoustic, thermal, electrical and mechanical insulation properties, as well as their resistance to fungi and bacteria, water repellency and lightness (19).

Plastics are man-made materials obtained by the industrial transformation of petroleum and other additives. Petroleum is a fossil raw material originated from the mix of organic sediments found underground. These sediments consist of remains of organisms that were submitted to high temperature and pressure for millions of years. Coal and natural gas are also formed under similar conditions.

Petroleum is a complex mixture of hydrocarbons that occur on Earth in liquid, gaseous, or solid form. The liquid form, also referred to as crude oil, is found underground and is the main form of petroleum that when transformed, gives origin to industrial polymers (20).

The Industrial Revolution in the 1800s brought an ever-growing demand for cheaper and more convenient sources of illuminating and lubricating oils, as well as more efficient sources of energy to replace the current ones: human and animal muscles, and the combustion of solid fuels such as wood, peat and coal. These forms of energy were inconvenient to extract and transport to the locations where it would be consumed. In contrast, liquid petroleum was found to be easier to transport and held a higher energy potential, when compared to older sources available.

Petroleum is found in underground reservoirs where ancient seas were once present. Deep beneath the Earth pressure is extremely high, so petroleum is naturally pushed towards the surface until it reaches an impermeable layer of rock, where it will stay stored in underground pockets. These reservoirs can nowaday be found both under dry land or the ocean floor which can be several hundred metres beneath the surface. In order to extract petroleum, Geologists, Chemists and Engineers research the soil after geological structures that typically trap petroleum. They go through a process called 'seismic reflection', which consists of setting small explosions and analysing the sound waves that travel through the area around the explosion. Sensors placed on the ground are able to interpret and distinguish the geological layout, tipping the possibility of petroleum reservoirs.

After in-depth analysis of a first core drilling (samples of rocks in the subsoil), the oil is extracted from wells through the installation of oil wells, specific plants that drill a very deep hole in the ground, and through a mechanical pump extract this fossil fuel from the ground.

The first well drilled specifically to extract petroleum was completed in 1859 in Pennsylvania by the American entrepreneur Edwin L. Drake. From that point on, wells were drilled in all continents, progressing the usage of oil and gas from only illuminants and lubrication to the major source of energy for several industries. Especially after the invention of internal-combustion engines, petroleum grew to become the main source of energy the global economy depends upon (21).

During the refining process called 'cracking', the initial stage of plastic creation, long chains of hydrocarbon molecules are broken through high temperature and pressure, allowing for the conversion of molecules into the basic unit of plastics: monomers.

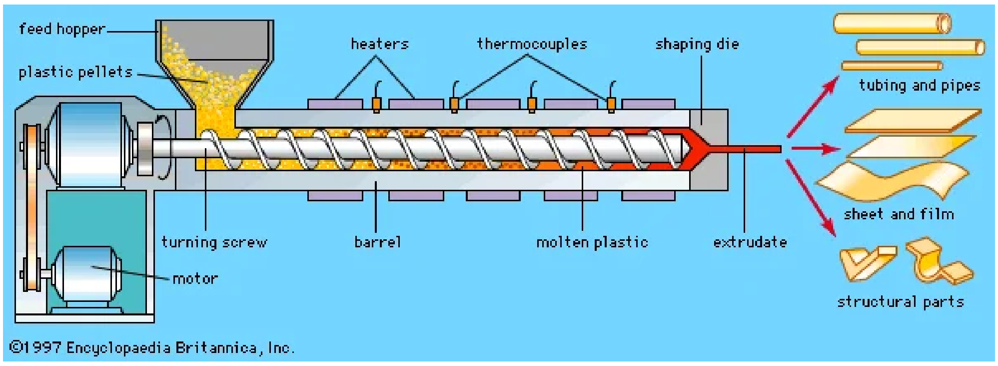
The subsequent process, polymerisation, consists of the re-merging of monomers into new long molecular chains by means of heat, pressure and catalytic reactions (22). Each of these chains will acquire different properties, depending on the monomers used and their combinations. Polycondensation is another equivalent process to create plastics, where polymers are obtained by subtracting 'waste' molecules, such as water, formed during the reaction of monomers.
Examples of polymers obtained through polymerisation are polyethylene, polystyrene and poly(vinyl chloride), whereas polyester and polyamide (PA) are examples obtained through polycondensation.

During compounding, various blends of materials are melted and mixed in order to make formulations for plastics. An extruder is used for this process, followed by pelletising the mixture. Moulding processes such as extrusion, calendering, injection and blow moulding, and thermoforming can then be used for transforming the material into semi-finished or finished products. It is during this phase that the material is shaped, coloured and resized, depending on the design and properties necessary for the final product (23).

Plastic moulding processes (24)

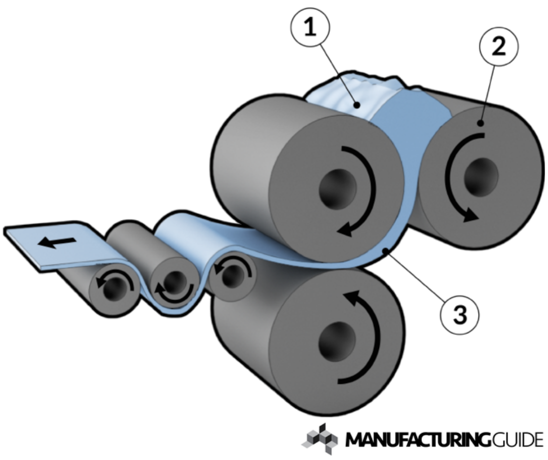
Extrusion

Melted polymer is forced through an orifice with a specifically shaped cross section. When pushed through the orifice, the plastic will obtain the constant shape of the cross section, the material is then cooled off so it retains the new shape. Materials produced by extrusion: films, sheets, tubing, pipes, structural parts.

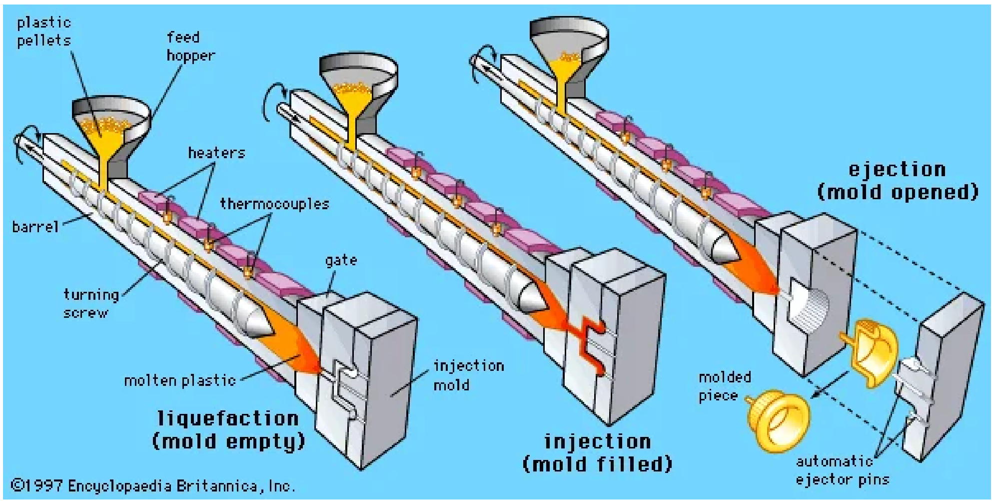


Calendering

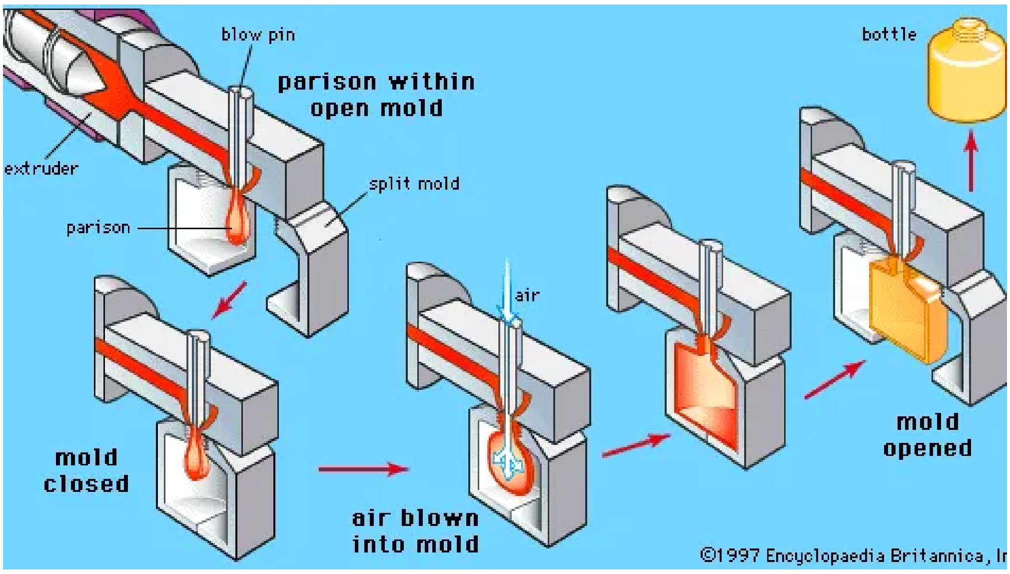
A polymer mixture '1' is heated and then fed between a pair of co-rotating main heated rollers, calenders '2'. The mixture is continuously pushed through pairs of calenders with smaller distances between them '3', until the plastic sheet acquires a desired thickness '4' (25). Calendered PVC sheeting is, for example, produced in this manner.



Injection moulding
Melted plastic is carried through a gate into an already cool metallic mould. Once the plastic is solidified, the mould is unclamped and opened, revealing the shaped plastic part.



Blow moulding
This inherited method from glass forming consists of a thermoplastic hollow tube, parison, being formed by extrusion or injection. In heated form, this tube is sealed at both ends and then blown up via an opening pin. The expansion of this tube is carried inside a mould with a cold surface. The wall thickness of the final shape can be programmed when the parison is shaped before the blowing. After being shaped, the mould is opened and the final shape revealed.



Thermoforming

A heated plastic sheet is pulled into a female/male mould by pressure or vacuum. The mould cold surface will cool off the plastic, solidifying it in its final shape. Cups for cold drinks in polystyrene or poly(ethylene terephthalate) (PET) are examples of products produced this way.

The development of plastic use in society

Natural polymers, such as amber, tortoise shells and ivory horns have been used by mankind since ancient times. Materials such as clay and chalk were also often modelled into objects and tools that required polymer properties of, for example, plasticity and rigidity. Synthetic plastics were first developed between 1861 and 1862, when English metallurgist Alexander Parkes was undergoing studies on cellulose nitrate. The material that he isolated was the predecessor to the development of the first plastic, Celluloid, and was patented as the first semi-synthetic plastic material: Parkesine, of commercial name Xylonite. Its composition is a mixture of nitrocellulose, camphor, alcohols and castor oil (26).

In the 1860s, the American Hyatt brothers commercially spread the application of Celluloid for the production of common objects such as combs, piano keys, knife handles and billiard balls, or more technical applications such as dental impressions, replacing more rare materials such as ivory and tortoiseshells. Those objects were produced by mixing solid cellulose nitrate and camphor, heating the mixture until soft, and then remoulding it into the desired shapes.
Celluloid was popularly used in the 1880s on collars and cuffs for men’s clothing, and the development of superior solvents allowed the material to be used on various applications such as flexible film for photography, side windows for cars. During the First World War the material began to be employed in coatings for the booming auto and aviation industries (27).

In 1907, Bakelite was invented by Belgian chemist Leo Baekeland and became one of the most used polymers in the beginning of the century. Bakelite was easier and quicker to mould when compared to celluloid, and was also less expensive to make. This gave products made out of this resin an enormous advantage in mass production processes. Bakelite is a thermosetting resin, meaning that once moulded, it retains its shape even if heated or subjected to various solvents.
These properties and advantages allowed Bakelite to be broadly used for specific emerging industries, such as electrical and automobile (28).

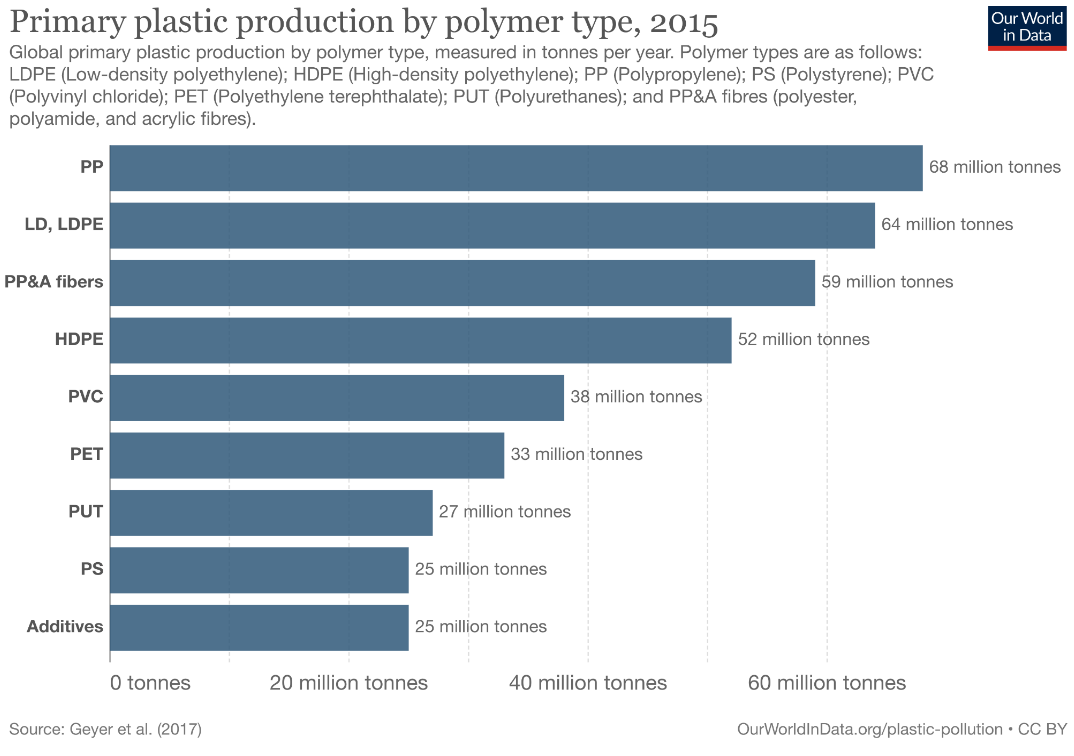
During the first three decades of the 1900s, Celluloid was increasingly replaced in the industry for less flammable and more versatile materials such as cellulose acetate, Bakelite and new vinyl polymers.

German chemist Eugene Baumann first prepared PVC in 1872, but it wasn't until 1913 when PVC was patented by German inventor Friedrich Heinrich August Klatte, when he used sunlight to initiate the polymerisation of this plastic.

PVC is a colourless and rigid thermoplastic that can be made into a number of forms, including foams, films and fibres (29). It is manufactured by bulk, solution, suspension, and emulsion polymerisation of vinyl chloride monomer, using free-radical initiators.

Initially, the extreme rigidity of the material limited its commercial applications, but in 1926, when trying to dehydrohalogenate PVC to obtain a rubbery polymer that might bond to metal, Waldo Lonsbury Semon (B.F. Goodrich Company in the USA) obtained plasticised PVC instead (30).

Due to its flexible properties, this new version of PVC went on to obtain higher commercial success, becoming in 2015 the 5th most produced polymer. Its more rigid and low flammable form is used for the production of pipes, conduits, payment cards, window and door frames. The plasticised PVC is more familiar to consumers and is used for electric-wire insulation, garden hoses, coated-cloth products such as faux leather.



During the 1920's, Hermann Staudinger, a chemist from the University of Freiburg, started theoretical studies on the structure and properties of polymers. The 1930's and the Second World War time mark the transition of plastics to a more mature phase, especially when establishing divisions on the modern industry: petroleum was defined as a raw, crude material from which to start production from, while the processing, production, and moulding techniques were increasingly improved and adapted to attend the mass industry needs.

In 1935, Nylon (polyamide) was synthesised for the first time by American chemist Wallace Carothers. The war stimulated the need to find replacements for unavailable natural products, which created a fertile condition for the creative development of plastics and its applications. This material went on to find various applications with the American army troops and with the general public: from women's stockings to parachutes, the era of synthetic fibres began.
Departing from Carothers work, Rex Whinfield and James Tennant Dickton (Printers' Association of Manchester) patented poly(ethylene terephthalate) (PET). This polyester obtained success in the period after the war in the production of artificial textile fibres, which is to this day popular. PET is lightweight, shock resistant and transparent. These properties favoured the entry of PET in the food packaging environment later, in the 70's, when the PET bottle was patented by Nathaniel Wyeth as a container for carbonated drinks.

After the war, military inventions and discoveries flooded into the commercial world. In the 50's, melamine-formaldehyde resins allowed the production of cheap and resistant laminates for furniture, while synthetic fibres entered the fashion market as modern and practical alternatives to the natural ones. These post-was years were also marked by the rise of use of polyethylene, industrially produced from 1957 onwards, entering homes all over the world in the form of packaging, appliances or textile, and feeding a high economic growth.

The 60's confirmed the presence of plastics as essential in the daily life of people all over the world. Objects of design and art elevated the perception of the material to sophistication, making plastics grow to become associated as fashionable and modern, objects of desire on western societies.

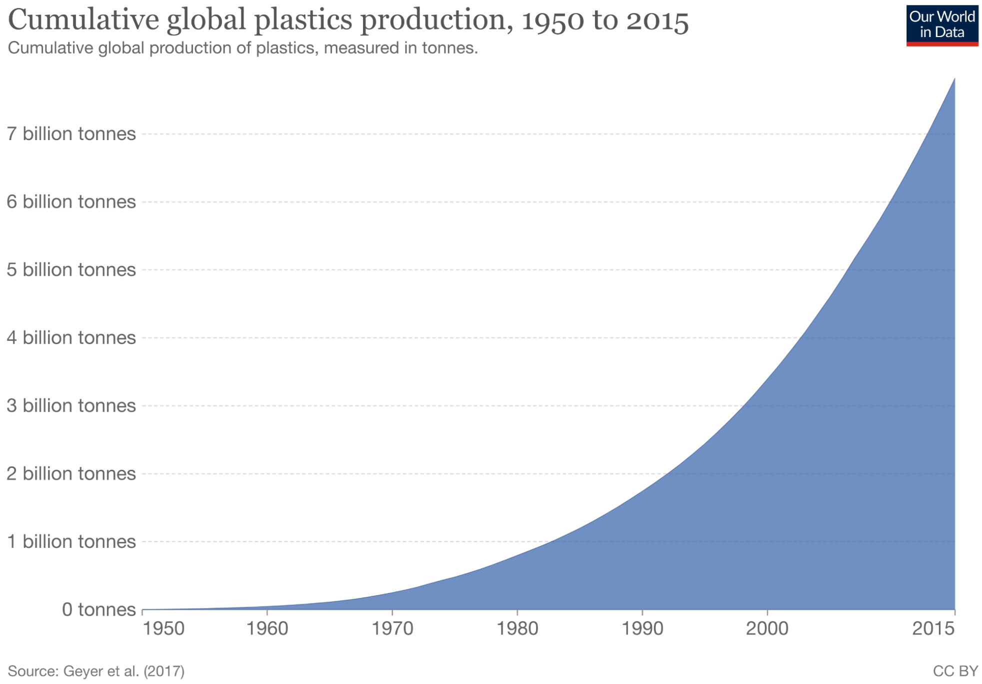
Due to the remarkable creative application of polymers, and their physical and chemical properties, since the 50s, a rapid growth in global plastic production took place. Plastics became the most popular material in the world which is not obtained exclusively from the use of substances found in nature, as is the case for other types of products such as paper, which derives from wood processing (cellulose) (31).

The following decades are marked by great technological advancements: progressive and innovative applications of plastics, also thanks to the development of "technopolymers", high performance plastics:

- Polymethylpentene (TPX), used above all in clinical laboratories, is resistant to sterilisation processes and is perfectly transparent
- Polyimide, thermosetting resins that do not alter its compositions up to 300°C, which allows usage for automobilistic engine components and microwave ovens
- Polycarbonate, used for bulletproof shields and helmets for astronauts

Among others, these high performance plastics have incredible thermal and mechanical resistance properties which are still under exploration. Often, their properties are superior to special metal alloys and ceramics, allowing for the application in the production of turbine blades, components of jet aircraft engines and pistons for automobiles (32).

After the 50s, the annual global production of plastics nearly 200-fold to 381 million tonnes in 2015. (33)



(33)

Throughout time, this major commodity has gained several applications in commercial and industrial products, becoming a symbol associated with progress and innovation, especially during the first decades of production and use, when the environmental impacts of plastics were not yet clear.

Plastics offer great advantages for innovation and application in new technology, as the material is relatively inexpensive to form and shape, while its properties are versatile. The combination of innovation, low manufacturing costs, and high variety of applications rendered plastics a great economic advantage when compared to other materials.
Polymers seem indispensable to the western lifestyle and are present in most everyday items such as home appliances and consumer products packaging, as well as in more high tech applications, such as optical fibre cables used for internet access and solar panels for renewable energy generation.

Unfortunately, society came to understand that the production and distribution of plastics is accompanied by harmful impacts related to its production processes, and to poor entrenched systems and methods implemented for waste disposing and treatment (34).

In order to contribute to the sustainable development agenda outlined by the United Nations in 2015, it is important to note and act upon not only the positive usage possibilities of plastics, but also with awareness about its potential detrimental consequences to society at a global level. It is undeniable that a great deal of modern industrial development happened due to innovation around plastics, but as governments, businesses and individuals learn about the impacts of climate change and inconsequent waste management, it is necessary to look forward to limiting the application and handling of plastics to only what will bring society closer to becoming self-resilient (35).

FIGURE 6

Main Plastic Resin Types and Applications in Food Packaging

Source: (48)

Plastics in the environment, its consequences to ecosystems and human health

The approach to evaluating our global dependency on plastic and its impact on the environment and animal life requires not only addressing all phases of plastics' lifecycle, but also the possible exposure pathways of additives used and released throughout the full process. By understanding the full lifecycle of plastics, and its impact on health, from manufacturing to waste management and recycling, one can be amunited to make informed decisions about the future of plastics production, consumption and end of life cycle (36).

1. Extraction and transport
   Fossil fuels are firstly extracted from well heads or drill pads, and then transported via pipelines or rails to refineries and processing plants.

   Known impacts to human health

   - Air pollution: During this phase, air pollution is generated via gases released during production, processing and storing. During 'pre-production', excess gases are vented or flared, increasing the release of toxic chemicals in the air, therefore lowering the air quality in the areas around extraction plants (37) (38). The diesel fuelled trucks used to transport water, sand and other materials are also contributing factors to air pollution during this phase. When inhaled, toxic chemicals such as BTEX chemicals (benzene, toluene, ethylbenzene and xylene) and other small liquid particles mixed in the air can lead to cardiovascular diseases and respiratory conditions such as shortness of breath, pulmonary inflammation and aggravation of asthma symptoms (39).

   - Ozone: Further away from extraction and storage facilities, communities are also impacted by gases and other pollutants such as volatile organic compounds (VOCs). When mixed with oxides of nitrogen and exposed to sunlight, these VOCs create ozone, resulting in ground-level smog pollution which is harmful to human health (40).

   - Water: Drinking water resources are also vulnerable to spills, improper handling of wastewater and faulty fracking infrastructure. Fracking wastewater is a blend made from the water used to frack, salts, toxic chemicals, organic matter and natural radioactive material. When improperly handled, this blend may be leaked into groundwater, which is then used as local drinking water supply (41). In four US states, 6,648 fracking-related spills were recorded between 2005 and 2014 (42).

   - Pipelines: The transportation of gas and oil from extraction points to refineries and ports requires large pipeline infrastructures (43). These lines are buried underground and prone to freezing, corrosion, breaking and leaking, eventually increasing human and environmental exposure to toxic chemicals. North American pipelines used to carry oil, gas or wastewater were responsible for more than 7.000 spills, leaks and accidents from 2009 to 2017 (44). Besides that, compressor stations, which pressurise gas to ensure a controlled flow in the pipes, create additional air emissions (45) (46).

Fossil fuel extraction and transport is the first phase of plastic production. In order to understand the full impact of the toxic impact of plastics, the above effects are considered in the full plastics life cycle. To reduce the negative impact of plastics on health and on the environment, it is key to rethink production models and reduce the extraction and transport of oil and gas.

2. Refining and manufacture

Through processing in refineries and crackers, petroleum is transformed into polymers. Those virgin polymers are in turn combined with a broad range of additives to render each polymer different characteristics and properties such as colour, resistance to physical stress, impermeability to light and oxygen, prevention to bacterial growth, etc. These polymers are then turned into products for use in all industries and consumer markets.

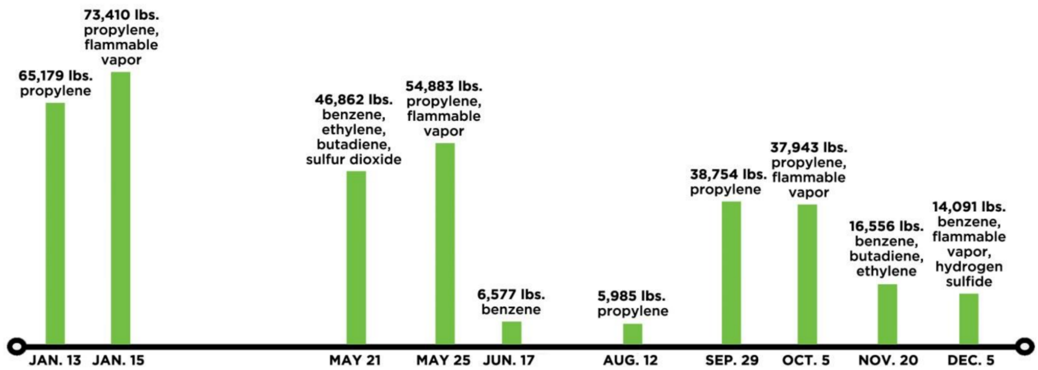
The refining and manufacture of plastics has a significant impact on human health, in particular to communities located nearby industrial plants. These communities face daily threats of daily exposure to toxic chemicals and potentially to consequences of accidents in the industrial plants. Typically, these communities consist of marginalised minorities, who generally have less resources for resisting and challenging the industry. The impacts of this phase are exacerbated by poor governance and communication with these communities.

Known impacts to human health

- Air pollution: Plastic refining and manufacture results in the release of many hazardous air pollutants, as many chemicals fundamental to producing plastics are such pollutants. Hazardous air pollutants are air toxics that are suspected to cause cancer, reproductive and birth defects, or other serious adverse human and environmental effects (47).. Many of these chemicals inflict an especially serious threat to human health, as they are known as to cause cancer and other respiratory and reproductive issues. An aggravant is that some of these chemicals can be difficult to detect, as some are colourless and tend to have mild to no odour. Below is a non-comprehensive list of the worst chemicals used and released during refining and manufacture (48):

- 1,3-Butadiene
- Benzene
- Styrene
- Toluene
- Ethane
- Propylene and Propylene Oxide
- Polycyclic aromatic Hydrocarbons (PAHS)

- **Risks of accidents:** Communities that are located near plastic industry plants are especially vulnerable to impacts of plastic production. They are exposed to various toxic chemicals in much higher levels, and are at constant risk of consequences from possible incidents and accidents in the industry. Industrial fires, explosions and chemical releases are surprisingly common, with, for example, an ExxonMobil refinery and chemical plant in the USA reporting 76 incidents in 2013, averaging more than six per month (49).



In 2013, Baton Rouge (Louisiana, USA) facilities of ExxonMobil released more than 360,000 pounds of toxic substances in the environment. Source: Adapted from LBB 2014A

These incidents not only release more chemicals in nearby areas, exposing inhabitants, but they also increase threats to workers in the plastic industry. Workers risk injury and death, and face long-term health issues due to increased exposure to chemicals. Recording of these risks is not always apparent, as they are subject to 'acceptable limits' of air toxics. In the USA, injuries and death numbers are only attributed to companies once they are suffered by official employees. This excludes external contractors, who often conduct the most dangerous jobs. As an example, in 2005, 15 external workers killed in an accident (50) at a British Petroleum (BP) facility in Texas were not attributed to BP's records (51).

The problems that workers and nearby communities are faced with when exposed to toxic debris and accidents are exacerbated by the lack of access to information, and by the bureaucratic and social barriers to raising concerns to companies and public authorities. Access to information about toxic chemicals and its effects is fundamental to evaluate risks and mitigate consequential harm. Governments and businesses alike are responsible to ensure communities are well informed about the risks their community is exposed. The development of accessible, non-bureaucratic procedures to information is needed, as well as better safety and security procedures, and the development of emergency plans of action, emergency funds and emergency structures of personnel to mitigate harm once accidents happen.

3. Consumer use

Plastic products have different lifespans. A disposable plastic cup will be used only once before becoming waste, while a television case and the interior console of a car will be in use for several years. For less environmental impact caused by plastic waste, it is preferable to make use of reusable products and/or products with a longer lifespan.

Whether plastic products are used for a shorter or longer period of time, they can have a negative impact on human health. Wear and tear causes some of those plastic products, such as tires, textile fibres and plastic bottles, to degrade and shed toxic additives, micro- and nano plastic particles and fibres in the environment and into food.

The most significant market for plastic nowadays is packaging. In 2015, 42% of all plastic ever produced comprised packaging goods (52), while 19% is applied in building and construction, and 39% of plastics are produced to become electric components, industrial machinery or to be used in transportation.

Chemical additives, plasticizers and plastic particles

The impacts of plastics on human health can be distinguished between the effect of plastic particles in the body (micro- and nano-plastic particles), and the effects of chemical additives, plasticizers and contaminants associated with those particles.

Recent emerging data show the presence of plastic and additives in food, air and water consumed by people. The research done around the topic of plastics and their consequences to human health are fundamental to question the outdated belief that all plastics have bettered human life. While the material has desirable properties and useful applications, it shows to not always be inert and safe for human consumption and interaction with ecosystems.

Plastic products can leach chemical monomers, some of which are harmful to humans. Based on carcinogenic monomer release, the most harmful plastics include polyurethanes (used to produce furniture foam, carpet backing and bedding), PVC (used to produce pipes, packaging and cable coatings), epoxy resins (used to produce coatings, adhesives, fibre-glass and carbon fibre), and polystyrene (used to produce food packaging and hard plastic in consumer products)(53).

In the manufacturing process, chemicals and additives may be used to create polymers, including initiators, catalysts and solvents. Additionally, stabilisers, plasticisers, pigments and flame retardants are used to provide characteristics to polymers. Other additives can also be used to inhibit degradation, regulate strength, rigidity and flexibility, or to prevent microbial growth.

These additives are often not bound to the polymer matrix and have low molecular weight, which make them more vulnerable to be leached in the surrounding environment, including water, food and body tissues (54). PVC is the polymer mixed with the most diverse variety of additives, including plasticisers to make it flexible, and heat stabilisers (55).

When used plastic products reach the environment in the form of micro- or macro-plastics, it is slowly degraded into smaller particles that contaminate its surrounding environment. Microplastics are spread in air, water and soil, releasing toxic additives in the environment and making them available for human and animal exposure via inhalation, ingestion or topic contact (56).

Known impacts to human health

- **Release of compounds in food and beverages:** During the manufacturing process, compounds are used in plastics to render them certain characteristics. For example, Bisphenol A (BPA) is used in the making of clear, hard poly(carbonate) plastics and strong epoxy coatings and adhesives, while polybrominated diphenyl ether (PBDE) is added to plastics as a flame retardant. Both compounds have come under close scrutiny and regulation since they have been detected in humans and are known to disrupt the endocrine system. BPA migrates out of polycarbonate bottles into water in levels proportional to heat. The migration of BPA from epoxy-coated cans is of even higher concern (57).

BPA is found to mimic the natural female hormone oestrogen, while PBDE has shown to disrupt thyroid hormones and to be anti-androgen. Children and women of reproductive age are the people most vulnerable to such chemicals, which may interfere with synthesis, action and metabolism of sex hormones that in turn cause developmental and fertility problems (58).

These compounds have also been found to disrupt hormones of other animals in terrestrial, aquatic and marine habitats. Amphibians, mollusks, worms, insects, crustaceans and fish show effects on their reproduction and development, including alterations on the number of offspring (59).

Only a few of the thousands of chemical additives used in food packaging have gone under rigorous testing, and at least 175 harmful chemicals are used in materials that get in direct contact with food in the European Union and USA (60).

TABLE 4

Common Toxic Chemical Additives to Plastic

Toxic Chemical Additive	Products in Which They Can Be Found	Health Impact
Acrylonitrile	Drinking cups, acrylic carpet and other textiles, plastic furniture, 3-D printing, automotive parts, and appliances.	Carcinogen
Bisphenol A	Polycarbonate plastics, plastic tableware, dental fillings, and lenses for glasses. BPA is also used to make epoxy resins that are used as coatings in lids of glass containers and in the linings of aluminum cans. BPA is also used to coat some thermal papers.	BPA is an endocrine disrupting chemical. Breast cancer, prostate cancer, endometriosis, heart disease, obesity, diabetes, altered immune system, and effects on reproduction have all been tied to BPA's ability to disrupt the normal functioning of endocrine systems. In young children, BPA exposures before and after birth are linked to changes in brain development and behavior.
Cadmium	Used as a colorant and stabilizer in plastic.	Lung cancer, endometrium, and bladder and breast cancer have been associated with cadmium. Cadmium can also damage the body's cardiovascular, renal, gastrointestinal, neurological, reproductive, and respiratory systems.
Flame retardants	Plastic-based home furnishings (foam, upholstery, curtains and blinds) and electronics (computers, laptops, phones, televisions, and household appliances).	Some flame retardants are endocrine disrupting chemicals. Studies have also linked flame retardants to thyroid disruption, impacts on fertility and the functioning of the immune system, and harm to the development of babies' brain and nervous systems both before and after birth. Several flame retardants are banned from production or use under the Stockholm Convention because they pose an unmanageable threat to human health and the environment.
Lead	Lead is used as plastic stabilizers and has been found in plastic jewelry,[1] vinyl raingear,[2] lunchboxes,[3] and vinyl window blinds.	In children, lead can cause reduced growth both before and after birth, decreased IQ and increased attention deficit and problem behaviors. In adults, lead exposures are linked to decreased kidney function and increased risk of hypertension, nerve disorders, and memory problems.[4] There is no safe level of exposure to lead.
Perfluorinated Substances (PFAS)	Grease and stain repellant in plastic-based fabrics used for raingear, upholstery, and carpeting, and as a plastic coating on cookware.	PFOA and PFOS are linked to human diseases including pregnancy complications, low birth weight, testicular and kidney cancer, and thyroid problems. The Stockholm Convention POPRC recommended not using any of the fluorinated alternatives to PFOA and PFOS, *"due to their persistency and mobility as well as potential negative environmental, health, and socioeconomic impacts."*
Phthalates	Plasticizer used to make plastic soft and pliable.	Phthalates are endocrine disruptors. They harm the reproductive and nervous systems, especially in children before and after birth. Deformities of the penis and learning and behavior problems are all associated with phthalates exposure.[5] Studies have also shown that the higher the levels of phthalates are in a home, the more likely children in that home are to have asthma or other respiratory conditions.[6]
Styrene (also known as Vinyl Benzene)	Polystyrene plastics and expanded polystyrene.	Carcinogen
Vinyl Chloride	PVC: plastic furniture, carpet backing, packaging or wall covering.	Liver cancer
SCCP	Plastic consumer product, children's products.	SCCPs adversely affect the kidney, liver, and thyroid, disrupt endocrine function, and are believed to be human carcinogens.[7]

1 Center for Environmental Health, *Jewelry Brands with High Levels of Lead*, *https://www.ceh.org/campaigns/legal-action/previous-work/fashion-accessories/lead-in-jewelry/jewelry-brands-with-high-levels-of-lead*.

2 Center for Environmental Health, *Lead in Children's Raingear*, *https://www.ceh.org/campaigns/legal-action/previous-work/childrens-products/lead-in-childrens-raingear*.

3 Center for Environmental Health, *Lead in Lunchboxes*, *https://www.ceh.org/campaigns/legal-action/previous-work/childrens-products/lead-in-lunchboxes*.

4 National Institute of Environmental Health Sciences, Lead (October 12, 2018), *https://www.niehs.nih.gov/health/topics/agents/lead/index.cfm*.

5 Coalition for Safer Food Processing and Packaging, *The Everywhere Chemicals in Your Food*, *http://www.kleanupkraft.org/#info*.

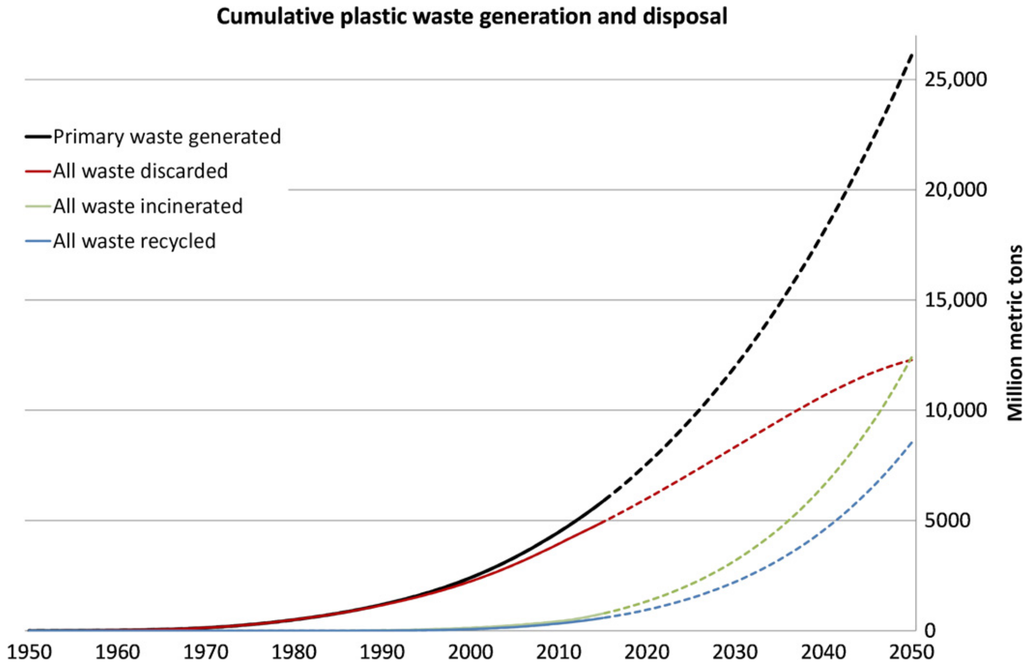
6 Center for Health, Environment & Justice, *PVC, the Poison Plastic Unhealthy for our Nation's Children and Schools*, *http://www.chej.org/pvcfactsheets/The_Poison_Plastic.html*.

7 UNEP/POPS/POPRC.11/10/Add.2 Risk profile on short-chained chlorinated paraffins Nov. 2015

Source: (48)

4. Waste management

   At the end of their lifespan, which can range from being very short for plastic food packaging and all single-use products, to much longer as in the case of construction materials, all plastic products become waste. The pace of global production and the diversity of materials distributed has outpaced the existing capacity of waste treatment methods. As of 2015, of the approximately 6,300 Mt of plastic waste generated, around 9% has been recycled, 12% was incinerated, and 79% ended up accumulated in landfills.



Source: (52)

In an attempt to manage the ever-increasing amount of plastic waste generated, cities and governments are turning to waste incineration as a method to give a destination to waste while generating energy. On the surface, waste incineration seems like an efficient solution, with ‘plastic-to-fuel’ and ‘waste to energy’ promising to reduce waste and generate more energy in return. Despite such euphemisms used by the waste incineration industry, all waste incineration techniques require thermal processes, such as mass burn incineration and gasification, as well as non-thermal processes like anaerobic digestion and landfill-gas recovery.

Emissions from waste incineration often results in toxic residues such as certain metals, (as mercury, lead, and cadmium), organics (dioxins and furans), acid gases (sulphur dioxide and hydrogen chloride), particulates (dust and grit), nitrogen oxides, and carbon monoxide (CO_2) (61). Smoke and particulates provenient from burned plastic and other waste can trigger and/or aggravate respiratory health problems in humans, while Polychlorinated dibenzofurans (PCDFs) and Polychlorinated biphenyl (PCBs) are carcinogens, and the released metals are known neurotoxins. Toxins from emissions, fly ash, and bottom ash in the burn pile can travel great distances and deposit on soil and water, eventually accumulating in the tissues of plants and animals in the food chain and finally entering human bodies (62).

Known impacts to human health

- **Toxic emissions from burnt plastic:** The waste incineration industry claims that the sophisticated emission control technologies they employ, results in the production of clean energy that decreases climate impacts and toxicity. However, significant research (63) shows that garbage incineration's pollutants and byproducts are detrimental in the short and long term. Toxic emissions from waste incineration affect nearby communities and workers who are directly or indirectly exposed to the residues that reach air, soil and water. Intoxication can happen through inhaling contaminated air, touching contaminated soil and water, and through ingesting food that was grown in a contaminated environment. The substances in the emissions tend to bioaccumulate in the food chain and pose a threat to ecosystems and the health of humans and animals. Burning plastic contributes to the fossil fuel composition of the energy mix while also emitting greenhouse gases into the environment. Newer incinerators in some countries use air pollution control devices such as fabric filters, electrostatic precipitators, and scrubbers. The filters do not prevent hazardous emissions from leaking into the air, such as unregulated ultra-fine particles that are extremely damaging to health (64). When the plant starts up and shuts down, or when the composition or volume of the waste changes, system failures may occur, and these malfunctions result in higher emissions than when under normal operating conditions (65). It is believed that over four million individuals died prematurely as a result of these types of airborne particles in 2015 (66). Incinerators are also disproportionately built in low-income and sociopolitically oppressed areas, causing hazardous ash and air pollution, as well as noise pollution and accidents in areas where people tend to have less resources to change the situation (67).

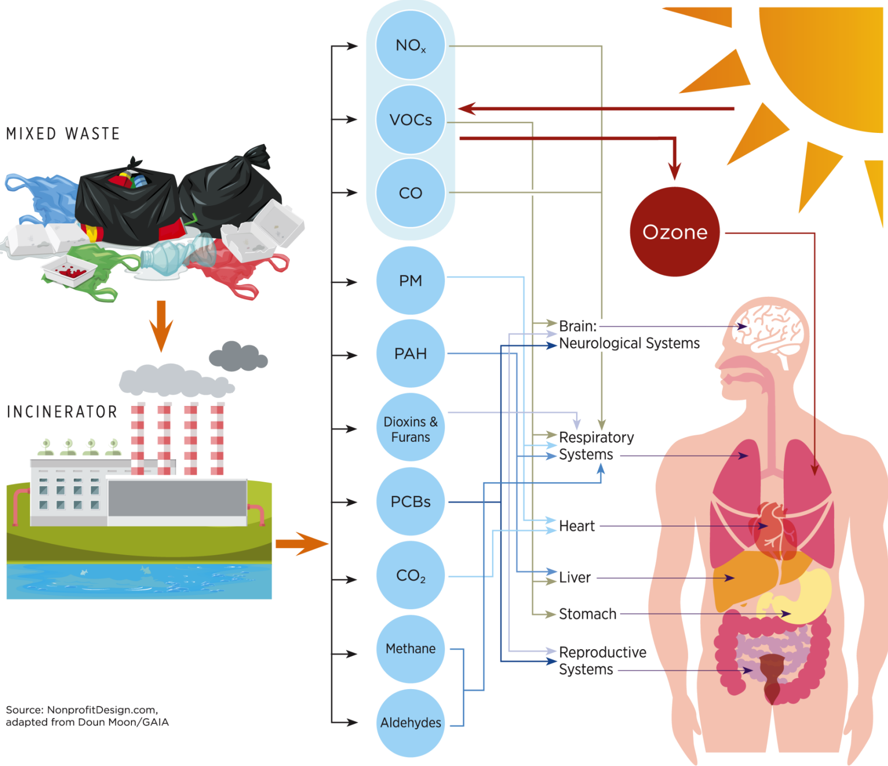
- **Incineration's Toxic Byproducts on Land and Water:** Incineration processes produce highly hazardous byproducts at various phases of thermal processing, in addition to toxic air emissions. Air filtering systems absorb pollutants, which are then transferred to incineration byproducts such fly ash, bottom ash, boiler ash (also known as slag), and wastewater treatment sludge (68). The bottom ash from the furnace is combined with the slag.
  Fly ash is a particulate matter that is discharged from the stack and contains harmful components such as dioxin and furans. Because fly ash is made up of microscopic particles

that are easily windborne and more likely to leak, it has a higher toxicity than bottom ash (69). Incineration generates ash, which creates a new waste management issue. Ash can wind up in a variety of areas, including landfills (ash landfills, hazardous waste landfills, and municipal waste landfills), mixed with cement, deposited in caves or mines, or dumped on open land, agricultural lands, islands, and wetlands. Metals and organic chemicals in ash can leach (e.g., dissolve and transfer from the ash to rain and other water that interacts with ash) and travel into groundwater or neighbouring surface water, extending the cycle of human hazardous exposure. Incinerator ash can impact human health through direct inhalation or ingestion of airborne or settled ash, in addition to endangering water supplies (70).

Ash residues from waste incineration endanger both local and global habitats, as well as human health. They contain significant levels of highly toxic persistent organic pollutants (U-POPs), such as those specified in Annex C of the Stockholm Convention (dioxins, furans, PCBs, and hexachlorobenzene), which are carcinogenic, mutagenic, and/or impair reproductive health (71).

Heavy metals such as arsenic, barium, cadmium, chromium, copper, molybdenum, nickel, lead, tin, antimony, selenium, and zinc, which come from plastic and hazardous household garbage, are also found in the ash (72). Heavy metal poisoning is known to occur as a result of industrial exposure, air or water contamination, and ingestion.

FIGURE 7
Toxic Exposure from Incineration



Source: NonprofitDesign.com, adapted from Doun Moon/GAIA

The burden of plastic pollution on human civilisation is increasing. Industrial and agricultural waste, particulates from car tyre wear, dust, landfills, wastewater, and intentional littering are all sources of plastic in the environment. Plastic is easily dispersed into the air, soils, rivers, lakes, and the ocean from marine, freshwater, and terrestrial habitats. It's not just unattractive, but it also has high potential to harm ecosystems and human health. Plastic waste is found everywhere, even in the deepest areas of the ocean, such as the Mariana Trench in the western Pacific, which is seven miles deep (73). Decades of poor waste management have compounded the problem, as has overproduction and consumption of disposable plastic.

Between 4.8 and 12.7 million metric tonnes of plastic were dumped into the ocean in 2010 (74). Though the statistics are difficult to verify, according to one study (75), the ocean may contain 5.25 trillion particles of plastic garbage, totaling 269,000 tonnes.
Weathering processes such as UV radiation, wind, and wave action break down plastic into micro- and nano-sized fragments in the environment. Many marine animals, including whales, have had large pieces of plastic detected in their digestive tracts (76). The effects of tiny particles of plastic on microscopic marine life have begun to emerge in the last two decades. Microplastic has been detected in a variety of commonly available fish and shellfish (77), as well as in street dust samples from cities all around the world, suggesting that people may come into contact with it (78) (79) (80).

Microplastics have been discovered in human excrement all across the world, according to unpublished studies (81). Microplastics are of concern because they have big surface areas, which may penetrate deep into an organism, attracting or releasing chemical additives and contaminants (82).

Plastic trash has been shown to have direct consequences on animals, including entanglement, digestive system obstructions, and toxicological effects. Microplastics' indirect effects on the environment and human health are particularly difficult to assess. The majority of studies to date have been conducted in a marine setting, and it is evident that microplastics interact with all aspects of ecosystems in ways that are still unknown. According to a new study, there may be broad-scale ecological concerns connected with plastic pollution, such as the health of fish stocks and modification of marine carbon storage, which might have long-term repercussions on food and climate security, in addition to human health impacts (83).

Though the need for action against global plastic pollution is urgent, policy discussions have reached the equivalent stage of global climate change talks only in 1992. There is a mandate to identify options, but discussions are slow, industry constriction is high, and concrete pledges are few (84). Scientists are pushing for worldwide rules to address all phases of the plastic lifecycle, such as limiting polymer and hazardous additive manufacturing, setting up plastic recycling and waste management objectives, and moving toward a circular economy, in order to reduce the burden of plastic waste (85).

Microplastics are predicted to become increasingly abundant in the environment, and more research is needed to determine how this may influence human health. Research is released on a regular basis, and laboratory (and field) methods are in the works to make results more comparable. Despite the fact that worldwide regulatory rules are still in the works, some medical professionals are already concerned about the occurrence of microplastics in food (86) (87).

It is predicted that the ingestion of plastic particles will have physical and toxic consequences on humans, resulting from the distribution of microplastics in the environment. Further study is needed to completely understand the impacts of microplastics provenient from various pathways of exposure such as air, food, and drink. It is challenging to design reliable human health studies to look at the toxicological effects of microplastics ingestion. Because humans are exposed to a range of harmful chemicals in our daily lives and experimental studies are unfeasible, large-scale population-based research would include a lot of confounding variables. Certain pollutants in food, such as mercury, pesticides, and certain industrial chemicals, are regulated in the European Union, but microplastics in human-grade seafood are not (88) (89).

The following paragraphs examines plastic pollution in human food via ingestion, inhaling and agricultural soil contamination.

Plastic ingestion

Besides the contamination of food and beverages via microplastics and toxic chemicals released in packaging, natural food chains are also affected by the release of these compounds in nature. Though not very extensive, most research to date regards seafood, leaving a gap in knowledge for both sea- and land-based food chain contaminations.

Plastic has been discovered floating in all oceans and in sediments, even at the deepest areas (89). Microplastics have been found in the stomachs of over 690 marine species, ranging from minuscule zooplankton to larger marine animals. Many commercially significant species have also been reported to be contaminated by microplastics (90) (91). Microplastics have been detected in commonly consumed species, such as Atlantic Mackerel, Herring, Anchovies, Scampi and Crabs (92) (93). One sample found microplastics in all samples of mussels purchased in UK supermarkets (94), and an analysis of species of dried fish available in local Malaysian markets concluded that consumers may ingest up to 246 pieces of man-made particles every year (95).
Studies on seaweed contamination showed that microplastics can stick to the surface of edible seaweed species, but the procedure of washing them before eating reduced exposure by 94.5 per cent (96). Commercial table salt sourced from sea, lake, and rocks have been found to contain microplastic particles (97) (98) (99). Differences in laboratory methodology might make comparing research difficult, standardising methodologies should make understanding the data easier in the future. The detection of microplastics in both rock and sea salt samples indicate that there is a high background level of plastic pollution in both marine and terrestrial ecosystems. Microplastics are found in many types of ecosystems, including terrestrial, marine, and freshwater. Bottled water, tap water, beer, honey and sugar have all been shown to contain microplastics. The particles might arise from a variety of sources in the environment which are difficult to trace, including water, waste treatment sludge used as fertiliser, processing and packaging (100) (101) (102) (103). Microplastics are not easily degraded. Micro and nanoplastics have been demonstrated to be carried from prey to predator in laboratory trials, suggesting that plastic-associated chemical additives and pollutants might be transmitted down the food chain (104) (105).

Researchers discovered that common beach crabs fed plastic-contaminated mussels ate the microplastic beads and fibres as well (106). Nanoplastics were shown to easily migrate up the food chain from an alga to a water flea to a rice fish, all the way to the top predator, a dark chub (107). The complicated interactions between marine life and microplastics demonstrate the numerous channels and mechanisms through which microplastics can infiltrate the food chain.
Microplastics can enter the human body via ingestion through food and drinks. Eating microplastics raises health concerns because of the potential for particle migration from the digestive system to other tissues and of microplastics as a delivery method for harmful substances. Plastic additives including phthalates, BPA, and certain flame retardants are known to be endocrine disruptors and carcinogens and are of special concern (108).
Due to ethical concerns about human testing, initial research on the possible consequences of the toxicity of microplastics involved laboratory and field experiments on marine creatures and mammals. Also, Polystyrene microplastics (5 m and 20 m) ingested by mice are found to accumulate in the liver, kidney, and digestive system, according to fluorescent microscopy (109).

Plastic inhalation

We are also exposed to microplastics through the air we breathe. Although research on microplastics in the atmosphere is still in its early stages, investigations in Paris, France (110) and China (111) have already indicated the presence of microplastics, predominantly fibres, in total atmospheric fallout.
Sources of airborne plastic pollution include indoor contact with sources of microplastic, such as carpets and furniture textiles, and fibres released from degraded plastics and films used in agriculture (112). Recently, it's been identified that one of the main sources of microplastics in the air consists of dust from vehicle tyre wear (113).

Exposure at work is thought to be considerably more harmful than exposure at home (114). Textile workers are exposed to higher amounts of synthetic fibres for longer periods of time than the general population. The impacts of worker exposure give insight into the possible human health risks of increased microplastics exposure, particularly of fibres. Interstitial lung disease, for example, affects 4% of workers in nylon flock plants in the United States and Canada (115), causing coughing, dyspnea (breathlessness), and reduced lung capacity (116).

Plastic contamination in agriculture soils

Food production and safety are both dependent on soil. The composition of human and animal diet is determined by the soil. It is the frontier between land, water, and the atmosphere and it is affected by various pollutants, including plastic. Microplastics' origins and transit in the terrestrial environment are poorly understood (116). Researchers in southeast Germany discovered macro- and microplastic pollution in agricultural areas where fertilisers containing microplastics and agricultural plastic treatments had never been applied before (117). According to recent research, terrestrial plastic pollution may be 4 to 23 times that of the ocean (118).

Microfibers from textiles and residues from plastic packaging are abundant in sewage entering municipal treatment systems (119). 80% to 90% of microplastics that enter treatment systems end up in residual sewage sludge (120). Because this sludge is frequently used as fertiliser in agriculture, plastic is commonly deposited on agricultural fields, where it can remain for lengthy periods of time (121) (122).
One researcher projected that sewage sludge contributes 63,000-43,000 and 44,000–300,000 tonnes of microplastics to European and US agriculture, respectively (123).

Plastic's effects in agricultural soils, as well as their toxicological and ecological effects, are still unknown to scientists. Concerns have been raised in certain research. Concerns have been raised as researchers emphasise the need for more study into how plastic degrades and leeches in different environments and conditions (as in soil, water, and under different conditions of temperature and pressure) (124) (125) (126) (127).

Potential health issues connected to plastic in soils, is the possibility of hazardous compounds being transferred to crops and animals. Endocrine disrupting substances such as phthalates, polybrominated diphenyl ether (PBDEs) and bisphenol A have been detected in fresh vegetables and fruit (128), (129) (130).
Although determining the exact source of specific contaminations is difficult, discoveries of plastic additives and harmful pollutants in vegetables and fruit should serve as signs for implementing precautionary measures to prevent the exposure of industrial plastics in nature.

A lifecycle approach to the impacts of plastics

Assessments of plastic's impacts in nature and society have improperly been focused on a single stage of the plastic lifecycle, and often on only a single exposure pathway within that stage. Each of those lifecycle phases interacts with the others and with the human body and environment in a variety of ways, many of which overlap. In order to assess the full scope of impact related to plastics, and to become equipped to make well informed decisions, it is necessary to approach the full lifecycle of plastics as one.

Health impact analyses that focus individually on product plastic components tend to neglect the hundreds of additives and their behaviour throughout the plastic lifespan. Adapting and implementing legal frameworks to promote transparency on the use of petrochemical compounds in all goods and processes, as well as enhanced independent research to cover knowledge gaps, isrequired to address plastic pollution.

Plastics have complex life cycles, involving a broad range of affecting agents. Decreasing harmful plastic exposure will need various approaches and different solutions. In order to adequately address the problem of plastic pollution and its effects on human health, we must ensure that we are not generating new and increasingly complicated environmental problems in the process of doing so.
Plastic manufacturing, usage, and disposal are all intertwined globally in supply networks that traverse countries, continents and seas. Until recently, attempts to address the effects of plastic on human health have mostly overlooked the global elements of the plastic lifecycle. As a result, local solutions that target a specific product stream are frequently offset by the introduction of new types of plastic, new exposure paths and new additives.

The present fragmented approach to solving the plastic pollution challenge will not work until efforts are taken in all levels of policy-making to understand the complete plastic lifecycle.
Due to a variety of factors, including the scale and complexity of impacts, the limitations of risk assessment systems, unknown data from cumulative effects of plastic exposure, and financial stakes in the industry, efforts to address the plastic pollution crisis have had limited success to date.
While the plastic industry's commercial interests are tremendous, the consequences to society are no less significant.

Despite being one of the most widely used materials on the globe, little is known about plastic's influence on human health. With increased plastic manufacture and use, human exposure to it increases. To date, research into the human health effects of plastic has concentrated on specific points in the plastic lifecycle, such as the transition from wellhead to refinery, the transition from store shelves to human bodies, and the transition from disposal to ongoing impacts as air pollutants and ocean plastic. Each step of the plastic lifecycle offers considerable health risk to humans. The lifetime implications of plastic portray an unmistakably poisonous image: the current life cycle of plastics poses a global danger to ecosystems and human health.

The public is becoming increasingly concerned about plastic pollution. Plastic packaging and single-use garbage have already been banned or taxed in more than 60 nations, with the goal of decreasing consumption and improving waste management (131), and 90 CEOs have signed up for the development of UNEP's legally binding agreement, including PepsiCo, Coca-Cola and Procter & Gamble (132).

In March 2022, on a historic occasion during the UN environment assembly in Nairobi, world leaders, environment ministers, and other officials from 173 nations agreed to establish a legally binding convention against plastics. The meeting called for the negotiation of a treaty encompassing the full lifetime of plastics, from manufacture to disposal, during the following two years. The director of the UN Environment Programme (UNEP) has called it the most important multilateral environmental agreement since the Paris Climate Agreement in 2015.

In parallel to the development of the convention, UNEP has pledged to work with willing governments and businesses across the value chain to shift away from single-use plastics, as well as to mobilise private finance and remove barriers to investments in research towards a circular economy. The resolution includes measures to recognise garbage pickers indigenous peoples' participation. It's the first time that garbage pickers, low-wage labourers in underdeveloped countries who scavenge for recyclable plastic and other commodities, have been acknowledged in a climate resolution (133).

Payments: past, present and future

Barter and the invention of metal coins

(134)

The pursuit to survive through social interaction, and the need to exchange products, services and objects, are foundations of mankind's social and economic development.
In the early days of civilisation, the exchange of one commodity for another marked the beginning of payment transactions. At first, each community defined their own means of payment according to the availability of commodities. When the fishing season was abundant and there would be fish in excess quantity in a community, this surplus would turn into bargaining chips for something another community might have planted and harvested in excess.

Common exchanges were sugar for tobacco, corn for potatoes, leather for wool. Originally, barter in this precarious form of economy were in natural forms and closely linked to basic needs of communities, such as eating and living. This initial form of exchange made new items become available in places where they were not present before, developing needs not previously known in communities.
Mankind developed towards means of production, building tools and cultivating land. Through exchange between valuable goods, as humans began to attach the concept of value to things, commodities started to be produced with the intent of not only survival, but of enriching and thriving communities.

Salt was discovered by mankind as a useful item of survival. Besides its food seasoning quality, salt became known for its antibacterial properties, ensuring the preservation of many kinds of foods. As it was difficult to extract, especially in land areas further from the sea, salt became a desired but relatively scarce commodity, which contributed to the evolution of the payment methods' history.
Many goods were easily perishable, as fish, or difficult to transport, as cattle. Those qualities did not allow for the accumulation of wealth and caused large swings in such commodities' values. Meanwhile, salt became one of the main means of payment, dating back to the Roman empire, where soldiers would be paid their 'salary' with salt.

A few centuries later, dating the 1500s, as Portuguese and Spanish colonists arrived in America, local tribes exchanged wood and local natural elements for mirrors, knives and different kinds of items that were later used to attract wildlife interest. At that time, European societies were concerned with the accumulation of wealth and goods, while indigenous people were mostly engaged with exchanging barter for survival. During the exploratory colonisation relationships of the following centuries, barter was intensely used in the contacts between local communities and colonising nations.

As a commodity becomes scarce, its demand increases, resulting in higher value. The need for a medium of exchange that was accepted and recognised by all came from the necessity to reduce variations of values of items between regions.

Some properties of metals, such as malleability, ductility, resistance to stress and environmental action made the demand for metals increase, as humans found practical and aesthetic uses for objects created with the material. Metal demonstrated advantages as a currency when compared to other commodities, as it was hard to deteriorate, divisible and easy to transport. The first coins were minted in copper, in the 7th century before Christ, in Greece. Exchanges between territories of Greece, Turkey and other areas across the mediterranean sea boosted trade, and with it, the new coins. The currencies made of metals had the inscriptions of the ones responsible for its release. The value of those metal units was established by States, and were connected to its scarcity, purity and weight.
The invention of coins consequently also addressed the problem of indivisibility. The possibility to insert sub-units allowed to facilitate business in a world of virtually uncontrollable variables. Soon metals allowed individuals to accumulate wealth and governments to collect tax in a seamless way.

With the advent of paper money signified a curious development in the history of payment methods. Paper did not hold the same traditional properties as metals, but it evolved into a method of higher value, restricting coins to lower values of cash.

Paper money

In the Middle Ages people began to replace coins for paper money. This happened as goldsmiths were started to be trusted to keep the valuable coins safe from robberies in their facilities. Upon the deposit transaction, as a guarantee of possession, goldsmiths emitted a paper receipt to the owners of the coins. Those receipts were the first paper money, which attested the existence of funds in valuable materials.

Goldsmith’s receipts began to circulate in communities while coins and valuable items remained safe and stored away from the streets. The rise of the first traders and bankers began while forms of paper money developed:

drafts, bills of exchange, promissory notes, checks. Paper money could be exchanged for metallic items again once the bearer wished to do so.

While coins were oval, square, polygonal and then finally reaching their final circular shape, paper money was already initially developed in rectangular shapes in a horizontal orientation. From the beginning paper money depicted cultural and language representing inscriptions.

Monetary system

The issue of coins and paper money, together with the definitions of circulation of these symbols of value, created the monetary system that determined the foundations of the current financial structures. Each system adopted a currency and a proximate base, in which the divisional currency of its unit was equivalent to one-hundredth of its value. Governments increasingly took charge of issuing paper notes and coins, and regulatory systems were developed in order to ensure balanced and fair transactions. The top-bottom interventions were put in place initially to prevent fraud. First fraudsters used to scrape the metal of coins, reducing its weight and value in an almost imperceptible way. One of the first anti-fraud features developed was thereafter the slots commonly found in the contour of coins.

The development of money shows us that the problem of divisibility was one of the first significant issues for which humans found a solution. Since the replacement of the commodity money, two processes — authentication (verification of currency's actual worth or the cardholder's identity, for example) and logistics (how we transfer wealth from one side to the other side, either by carrying paper money in the pocket or by using an electronic card installed in a smartphone) — have persisted in an evolving cycle, competing in speed with the development of new fraud methods.

Plastic money

Payment plastic cards were created to strengthen the market of payments. Payment cards can carry out transactions of any value, while being made of a material more durable than paper, and less valuable than metals. Users began to adopt this method for the benefit of not carrying cash or check when going shopping, others because they can charge credit cards just as their grandparents used to go in debt in shops by making notes of their shopping costs in a booklet. Those traits and practical benefits allowed for plastic to, in time, take over the majority of today’s payment transactions.

The first payment card emerged with the American company Western Union around 1920, which began to issue a small card to be used by known and trusted customers. This first card worked similarly to a loyalty card: card owners received credit from merchants such as hotels and gas stations, and if debts were paid within a certain deadline, customers did not pay any extra charges (135). In 1946, the first bank-issued charge card was created by John Biggins, a New York banker. ‘Charg-it’ quickly became a very popular payment method within the participating merchants. Soon many businesses such as department stores and oil companies began issuing their own ‘courtesy cards’.

In 1950, financial executive Frank X. McNamara founded Diners Club International, expanding the buy now/pay later concept to a membership model that could be used at multiple merchants. The Diners Club model quickly attracted clientele and inspired the first modern credit card of America: ‘BankAmericard’, an all-purpose credit card to be used at a broader variety of businesses. The methodology used by Diners Club to make profit is based on transaction and administrative fees. Merchants paid transaction fees and benefited from being able to offer the payment method in their stores to customers, while customers paid an annual administrative fee to Diners Club and received monthly bills listing all transactions to be paid.

By the late 1960s banks started issuing debit cards directly linked to customers checking or savings accounts. At first, debit cards were used only to withdraw money from Automated Teller Machines (ATMs), but as banking systems improved, debit cards were also used at merchants, gradually replacing the use of personal checks (136).

The post-war context in the United States was ground for tremendous economic growth in the country. The success of credit cards came due to the fulfilled payment commitment from their beneficiaries - which amounted to 40 thousand customers in only one year, in the case of Diners Club. Besides that, credit cards were the most immediate form of acquiring credit, and its operational advantages met the demands of the era it was created.

The late 1900s saw the US currency increase in value, as it began to play a single role in international economic agreements and contracts. The American middle class was emerging and reaching better standards of living, using generally only a fifth of their income to lay loans (135). Easy access to credit cards, along with the economic excitement of the time, led the same middle class to face negative financial consequences as they began to pay debts from one credit card with yet another credit card.

The main global payment schemes known nowadays came to be as a result of bank alliances. The American based Interbank Card Association (ICA) made it possible for credit cards to be accepted beyond state borders. As this association grew internationally it was renamed as 'Mastercard' in 1979, reflecting the global commitment to the growth of the company. 'VISA', on the other hand, was created in 1973 from the association of independent members 'National BankAmericard'. The associations combine cooperation between banks which form a network that establishes definitions for marketing and product specifications. The association model is dominant nowadays, it allows for banks to compete for customers and to stay ahead in terms of security and product developments.

Cards in the 70s held very low security standards. They were produced on manual printers and were delivered with simple sale receipts, and the first machines called 'Zip Zap' were bought by banks and were rented to retailers for low monthly rates. The lack of security resulted in banks coexisting with large losses due to fraudulent operations.

In 1974, ICA (soon later to become Mastercard) introduced the use of the Magnetic stripe, reducing risks for fraud by making it possible to track card transactions. The following years saw the introduction of more features, such as chips, NFC (contactless) technology, online monitoring systems and increasingly safer points of sale, to facilitate the payment journey to both merchants and customers, and to increase security against theft and fraud.

The future of payments methods: Mobile payments

Technology has advanced significantly during the past few years. Globalisation has been exponentiated by the possibilities the internet has been bringing us. The entrenchment in society of social media, smartphones, the era of digital applications. Even though it is challenging to foresee the direction in which this period of fast change is headed, a revolution in the means of payment is also unfolding.

Today, it is hardly surprising to share the prediction that mobile payments will become the most popular means of monetary exchange between private individuals. Rewinding back five years, this theme was still highly debatable, with arguments about safety, integration and acceptance ranking high in corporate meeting agendas.
The topics above, though not yet fully solved by the financial industry, are now seen no longer as arguments against the evolution of means of payments, but rather as challenges to be quickly solved by traditional

financial institutions, if they wish to remain relevant with their current customer base who demand convenience, security, instantaneity, low rates, and fully virtual environments, reachable for them at any time and place.

As discussed in the previous paragraphs on ‘plastic money’, the main processes in payment transactions involve mainly logistics and authentication, which causes payment methods to seek evolution in terms of security, convenience and price issues. From golden coins to plastic cards and small POS machines, we have seen a trend towards the dematerialisation of money and the structure around payment transactions.

It is not easy to convince consumers about new products and services when they are habituated to using traditional and well established offerings. The black swan theory event is a metaphor that describes an event that is perceived as a surprise, has major effect, and is often inappropriately rationalised after the fact with the benefit of hindsight. For instance, the introduction of Apple’s products iPod and iPhone were not at all expected by society, until their features were presented as well predicted needs that completely changed the way people and businesses interact. These products disrupted the latest existing hardware and software in the industry, and caused the creative destruction of traditional products and services.

CM Christensen, a professor of Management at Harvard Business School describes the following in his book ‘The Innovator’s Dilemma’:

- “Evolutionary Innovation improves the performance of an existing product, process or service, incrementally or radically.
- Disruptive Innovation brings a different value proposition, reduces performance, but adds new values or attributes. It is usually simpler, cheaper, more convenient, etc.”

This rare kind of rupture can offer industries the opportunity to envision a new set of attributes that will enable entirely different uses for their products and services, sometimes even resulting in completely new industries and markets. Disruptive technology arrives to dominate empty spaces in an existing market either by introducing new technologies with greater abilities, or by introducing cheaper and slightly lower-performance products that are constantly improved, eventually moving industry leaders (as an example of the latter, are digital cameras that widely replaced analogue cameras).

The payments environment has focused in the past decades in improvements to current systems already established in the market. Plastic cards have found improvements on security and convenience features.

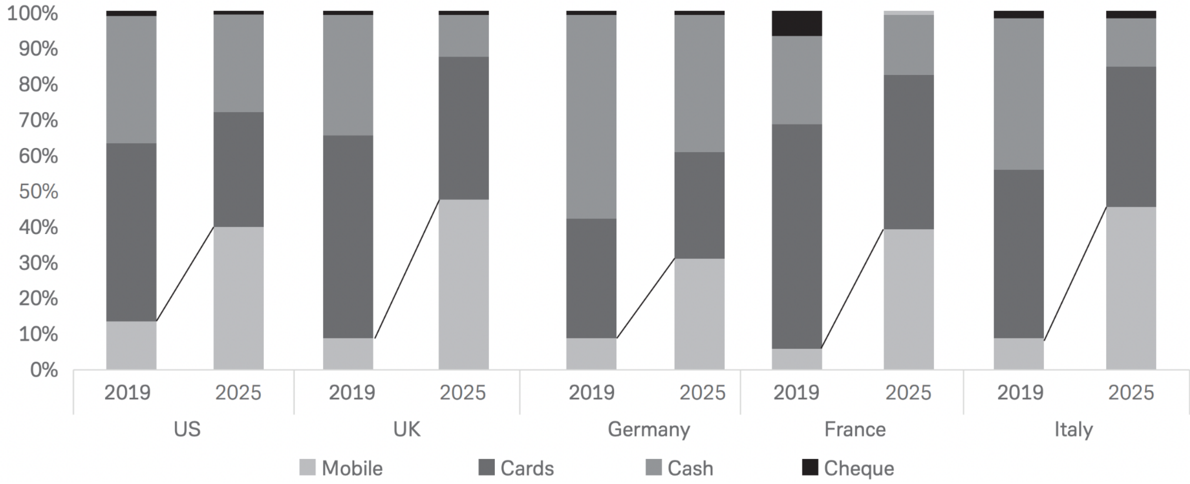
Processes and transactions around plastic cards have also improved, with Point Of Sale (POS) machines being introduced and having their security and mobility features upgraded. These developments are relevant to the industry, but are not considered to be disruptive as to reshape current payment standards.

Entrepreneurs Max Levchin and Peter Thiel, inspired by ideals of freedom, developed an online based payment solution directly from people to people (P2P) anywhere in the world. This solution excluded the participation of financial institutions and regulatory controls and came to be, in 1999, the industry-wide admired company PayPal.

Purchases made with PayPal accounts did not share the personal information of account holders with strangers and merchants. This made consumers feel safe and confident that the new company would care to keep their data, ensuring consumer's peace of mind in that respect while simultaneously allowing companies and individuals to transact in e-commerce, improving sales safety and decreasing transactional costs.

People frequently forecast the demise of cash when talking about the future of payments. According to a research by the Deutsche Bank (137), plastic cards will instead be eliminated even before paper money and coins, and mobile payments will take its place as the most popular means of payment. The research points out that digital payments have the potential to rebalance the global economic power.

Weekly in-store purchases per country in 2019 and 2025



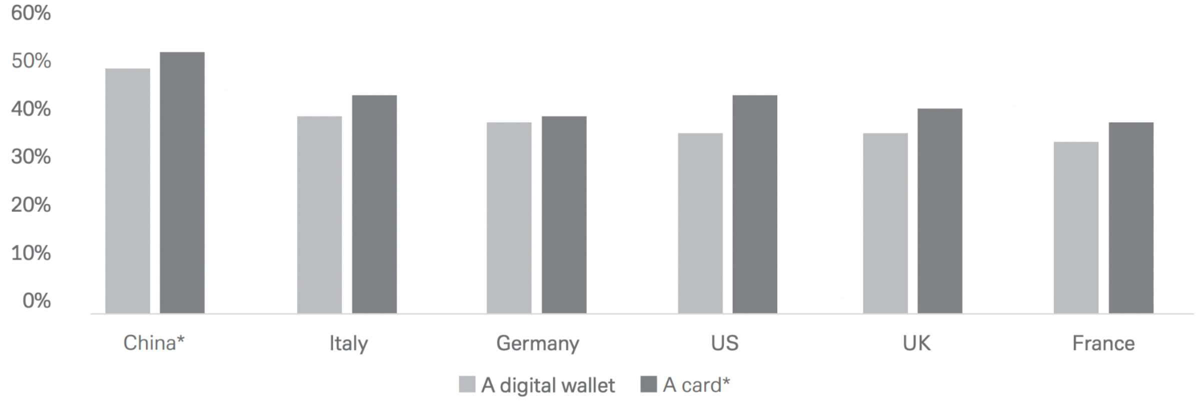
Source: (138) Note: Purchases with cheques are expected to be lower than 1% and nearly all cards are expected to be contractless by 2025 in the US, UK, Germany, France and Italy.

While cash will still be used in the longer term, digital payments are predicted to advance dramatically during the next ten years. The plastic card will eventually cease to be used as a result of this. In the US alone, it is anticipated that mobile payments will account for two-fifths of in-store purchases between 2020 and 2025, quadrupling their current share. Other industrialised nations are predicted to have comparable growth, but their levels of cash and plastic card use shrinkage will vary. In developing economies, the impact is likely to be felt even sooner. Due to the physical infrastructure needed for the implementation of plastic cards in a market, and to the contrasting ease of implementation of digital currencies' infrastructures, many consumers in emerging economy nations are making the switch directly from cash to mobile payments with smartphones, without having even used plastic cards. In India, cash payments went from 59% in 2000 to 30% in 2016. In China, cash payments dropped from 63% of payments in 2000 to only 11% in 2016. On the other hand, payments with cash and plastic cards are entrenched in the cultures of developed economies and will take longer to become obsolete. Forty percent of citizens in developed nations reported preference to traditional payments over digital wallets. However, despite the slower adoption rate, most people in developed nations believe that digital wallets will eventually replace traditional wallets by 2025.

In Europe, mobile payment technology is only getting started. Apple Pay launched in 2014, followed by Google Pay and Samsung Pay in 2015. Until 2020, 7% of Europeans have used their smartphones to make payments, having 70% of those began doing so only in the past two years. Though at a slower pace than in emerging economies, Europeans also expect a transition to mobile payments to happen in the next few years. Europeans who reported using active cards less than a year ago also reported to have used digital wallets more regularly. In fact, a third of Europeans intended to increase their use of mobile payments in the six months after the Deutsche Bank's 2020 survey.

Customers claimed that the quickness, ease, and lack of costs are the reasons why they increasingly choose to select mobile payments. With mobile payments, the psychological barrier to handle cash or enter PINs are no longer there. This is beneficial not only for the consumer, but also for businesses, which end up benefiting from the consumer thinking less of the value spent when paying with easier methods.

Customers think less about the amount they spend when using a card



*Source: (138) Note: The graph above shows the percentage of people who agree with two statements: "I tend to think less about the amount I spend when using a digital wallet" and "I tend to think less about the amount I spend when using a card." * For China the second column represents the percentage of people who agree with "I tend to think less about the amount I spend when using a mobile app."*

People have long used plastic cards in legacy systems, such as those in the US and Europe. As a result of tradition, consumers find it more challenging to switch to digital payments. Digital payment solutions must fight harder in these markets to displace conventional customer behaviour. Due to this, the US mobile payment app Venmo, which was initially merely a digital wallet, later unveiled a Venmo debit card that takes money directly out of a user's Venmo balance. This is a middle ground solution between electronic and card payment methods.

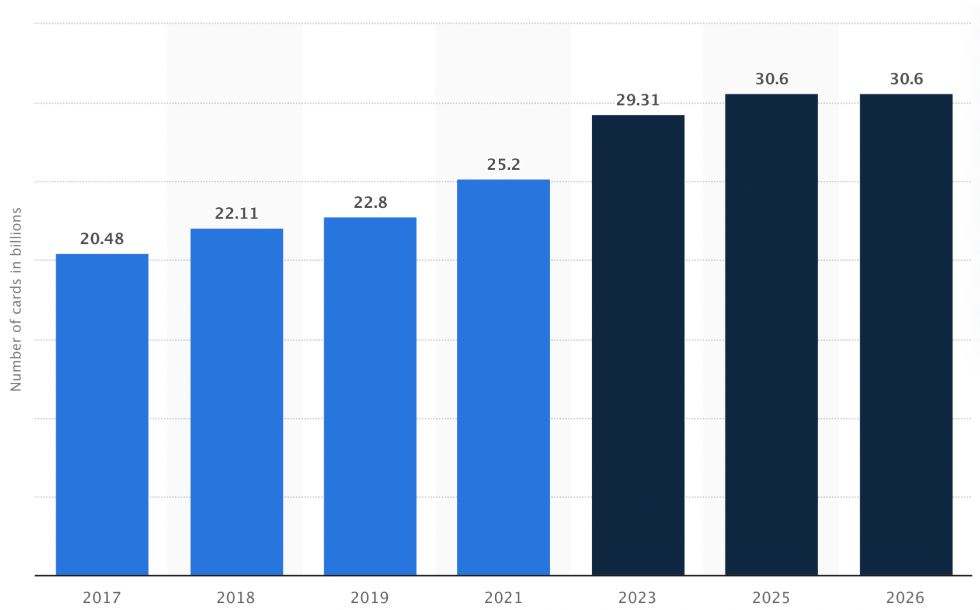
As an example, due to Germany's present demographics, preferred payment methods, and intended payment method usage, we can anticipate that cash will continue to be the most widely used in-store payment method over the next five years. In other places with emerging economies, it is anticipated that e-Wallets will rank second to cards as people's preferred payment method, with millennials favouring this approach the most.

Peer-to-peer payments and cryptocurrency are two technology advancements that potentially undermine card providers as payment methods continue to evolve quickly.
The primary function of card platforms is to enable payments between a payer's and a merchant's bank accounts. Card platforms will be affected by the emergence of peer-to-peer payments and electronic wallets enabling noncash transactions between people. Mobile applications can establish direct connections with bank accounts to guarantee that e-Wallet settlements are completed, instead of POS machines. These new apps and platforms could bypass companies that issue cards to customers if they are used frequently for merchant transactions.

Though prone to extinction, as the real dinosaurs in the payments evolution landscape, payment cards will continue to be useful for the foreseeable future, especially in developed economies, as shops catch up with accepting mobile payments and as consumers adjust to new habits brought by quickly developing technologies. For users of mobile wallets, the ever-present possibility of POS systems with NFC technology malfunctioning at merchants makes physical payment cards act as a backup in those circumstances.

More than 30 billion plastic payment cards are expected to be in circulation by 2026, still an increase of 18% when compared to cards in circulation in 2021. The next chapters will discuss ecological improvements to the production possibilities for plastic payment cards, while they remain present in the payments environment.

Number (in billions) of credit, debit and prepaid cards in circulation worldwide from 2017 to 2021, with forecasts for 2023, 2025, and 2026



Source: The Nilson Report, October 2021

Cryptocurrencies: the emergence of Bitcoin

In 2008, Satoshi Nakamoto, the online anonymous founder of Bitcoin (BTC), combined the existing peer-to-peer technology, encryption techniques, digital signatures and the newly social-media proven power of online networks to develop the BTC system. Nakamoto found motivation in the fallout of the 2008 banking crisis and intended to create a system that pledged to eliminate the possibility of corruption of currency trading and issuance. Instead of being reliant on governments, central banks or other centralised third-party institutions, the BTC system was built to rely on the value of currency transactions and its guarantees on the network and automated maths problem solving.

On Nakamoto’s words in a post in February 2009 in a P2P foundation blog (139):

> “[Bitcoin is] completely decentralised, with no central server or trusted parties, because everything is based on crypto proof instead of trust. The root problem with conventional currency is all the trust that's required to make it work. The central bank must be trusted not to debase the currency, but the history of fiat currencies is full of breaches of that trust. Banks must be trusted to hold our money and transfer it electronically, but they lend it out in waves of credit bubbles with barely a fraction in reserve. We have to trust them with our privacy, trust them not to let identity thieves drain our accounts. Their massive overhead costs make micropayments impossible. [...] With e-currency based on cryptographic proof, without the need to trust a third party middleman, money can be secure and transactions effortless.”

On the one hand, the distribution of property titles in Bitcoin and other subsequent cryptocurrencies restores money as a form of property. It is not trust that is being discussed, but rather property. In this regard, Bitcoin recalls the integrity and honesty of the gold standard currency. On the other hand, the new Bitcoin system propels us forward in time by permitting financial exchange between two people anywhere on the earth, regardless of whether they have a bank account or credit card. This distinguishes a crypto standard from the traditional gold currency and makes it more advanced.

BTC has gained enormous media attention in the following years to its invention. However, there is still a big gap of knowledge and understanding between what the media, governments and the general public, and what the growing mass of technologists and scholars believe Bitcoin is. Much has been written in the media about the dangers related to the anonymity of Bitcoin’s creator, the irreversibility of transactions and the possibility of easy use of the currency for money laundering and criminal transactions. Moreover, thus far, the fear environment created around the myth of an online anonymous creator, prevents, to a certain level, the rational assessment of potential benefits and shortcomings of cryptocurrencies. It is worth noting that traditional currencies are also used in money laundering and criminal transactions, and they are also difficult to recover once stolen.

Bitcoin is fundamentally a breakthrough in computer science. Based on decades of research on cryptography, it is the first practical solution to an old computer science problem called 'Byzantine Generals' Problem'. This problem is a game theory problem, which describes the difficulty decentralised parties have in arriving at consensus without relying on a trusted central party. In a network where no member can verify the identity of other members, how can members collectively agree on a certain truth? (140).

In relation to currencies: How does a society create a monetary system that all individuals can trust on and embrace? For a significant portion of history, societies have chosen to use uncommon items like shells or glass beads or precious metals as currency. The Byzantine Generals Problem was partially resolved by gold, since it was respected and recognised in decentralised systems such as international trade. Its weight and purity, however, remained unreliable to this day. Gold's partial inability to resolve the Byzantine Generals Problem led to the establishment and issuance of money being taken over by reliable central parties, typically governments. To promote confidence in the purity and weight of the currency, governments monopolised mints. For Bitcoin's creators, the Byzantine Generals Problem was not resolved by centralised systems, as trusted parties violated trust by seizing, debasing and changing money in order to correct economic and social issues. For them, in order for a currency to solve the Byzantine Generals Problem, it had to be verifiable, counterfeit-resistant and not based on trust.

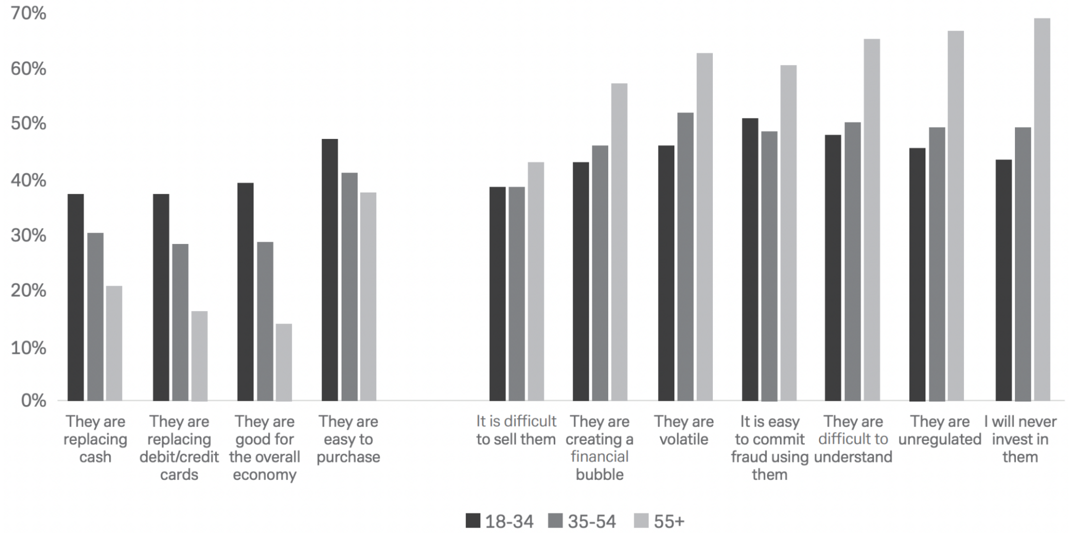
The Bitcoin solution uses a Proof-of-Work mechanism to establish a clear and objective set of rules for the blockchain. In order to add information to the blockchain, a member of this network must invest computer power into creating a block of information and publish proof of it. There can be no disagreement or tampering with the information on the Bitcoin network because the rules are objective. The method for deciding who can create new bitcoins is also objective, as is the set of rules dictating which transactions are acceptable and which are invalid. The history of Bitcoin is unchangeable because it is very difficult to erase a block once it has been committed to the network; the computing power needed to do so is not worth the result.

Operators in the Bitcoin network can thus always agree on the blockchain's current status and all of its transactions. Each node independently confirms the validity of blocks based on the Proof-of-Work requirement.

All nodes on the network will instantly identify fraudulent information as objectively invalid and disregard it if any member of the network tries to broadcast false information. Bitcoin is a system that is not based on trust, since each node can independently validate all data on the network, eliminating the need to rely on other users or regulatory institutions.

Cryptocurrencies are popularly seen more as a new additional method of conducting financial transactions rather than an essential or beneficial replacement for well established payment methods. Despite increased interest from society and well-known advantages, including security, speed, low transaction fees, ease of storage and relevance in the digital age, cryptocurrencies have not yet been popularly used as a form of payment.

Citizens who agree with the following statements about cryptocurrencies



Source: dbDIG Deutsche Bank Research. Note: include China, France, Germany, Italy, the UK and the US.

Cultural beliefs have an impact on how quickly cryptocurrencies are adopted. The conflict between privacy and convenience is the main cultural issue around cryptocurrency (141). As digital data is not created during a cash transaction, digital footprints are significantly reduced by the use of banknotes and coins. As a result, personal privacy is increased in these transactions because no third party, like a payment provider, will automatically obtain that transaction's data. When it comes to digital wallets and the extinction of plastic cards, customers strongly prefer digital payments since they are more convenient (138). For instance, cards and smartphones eliminate the need to carry cash and coins, and armoured trucks are not required to transport money to the bank on a daily basis by merchants.

Beliefs on these two opposites - privacy vs. convenience - differ per culture. A survey by the Deutsche Bank (141) reveals that people in advanced economies are more concerned about privacy than people in emerging nations. According to the survey, concerns regarding anonymity and traceability were expressed by 22 percent of Americans, 21 percent of Brits,

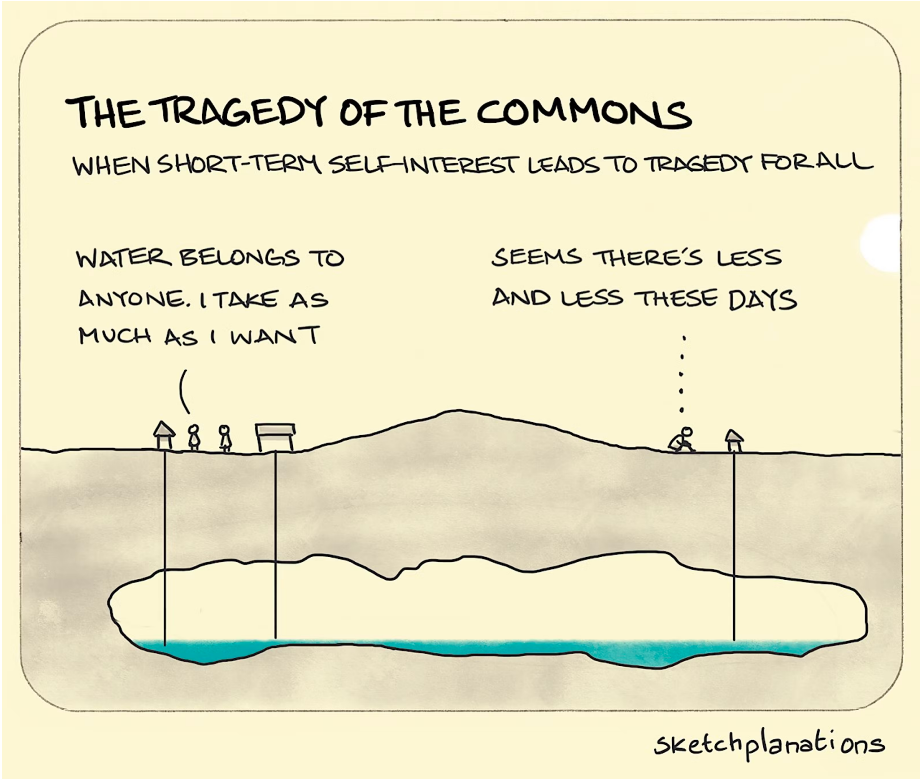
29 percent of French, 42 percent of Germans, and 19 percent of Italians. Similar worries were voiced by a tenth of the Chinese people who took part in the survey.
Due to the fact that cryptocurrencies aim to enable financial transactions that are digitally convenient and individually private, the conflict between convenience and privacy may diminish as the general population learns more about how cryptocurrencies and blockchain technologies operate.

Bitcoin as a potential new global monetary system

The remarkable technological breakthrough of blockchain is fascinating, and the prospect of a decentralised monetary system seems bright at first sight to a society that has developed low trust in banks and governmental institutions (142). The idea of replacing fiat money (regulated, legal currencies without a fixed value, unbacked by a tangible asset, issued by governments) by, for example, Bitcoin must be however faced with extreme caution.

Under a socialist civilisation, free of private banks and share markets, a system like Bitcoin's could competently characterise the global monetary system. In opposition to that, in the current existing capitalist global society, if Bitcoin was to replace fiat money, it would risk lacking the mechanism necessary to regulate the economy against depressions that end up benefiting the elite and harming the working class. In addition to that, its community-based democratic protocols would, surprisingly to many, be feared to do very little to be able to democratise the economy (143).

Considering the 2008 and the most recent Covid-19 crises as examples, suppose Central Banks were forced to rely on a spontaneous majority of Bitcoin users to approve significant increases in money supply (because these institutions lacked the ability to instantly create trillions of dollars, euros, pounds, and yen). The outcome would most likely be a financial and corporate catastrophe comparable to that of 1929. Such crises are bound to strengthen the far-right elite side of society, resulting in an extremely socio-economic segregated and unequal scenario. There would be nothing technically stopping the Bitcoin community from agreeing to instantaneously increase, or even double, the money base. However, the Tragedy of the Commons would ensure that Bitcoin owners experience the typical prisoner's dilemma dynamic, which prohibits the increase in money supply required to dampen the retraction of jobs and businesses. Furthermore, the extremely unequal ownership distribution of Bitcoin aggravates this issue, as wealthy Bitcoin owners suddenly have strong financial incentives to limit the expansion of the money supply (since such restriction would boost their own profits at the expense of public interest).



Source: (144)

Contrary to popular belief, under capitalism, the dominance of Bitcoin would not help democratise the economy. If Bitcoin were to take over the anchor of the global monetary system, the value of currencies, property over land, resources and machines would remain similar, while the bulk of shares traded in financial markets would continue to be owned by pension funds and private equity firms. The main change would be that Central Banks would cease to exist, while Bitcoin owners would determine the global money supply as mentioned above.
Private firms would continue to operate as per usual, often with monopolistic and exploratory practices. Private banks would likely develop derivatives based on Bitcoin, which would work as means of exchange. This would eventually lead to the build up of Bitcoin bubbles and their eventual bursts. Once a depression is installed, society would sadly depend on the faulty regulatory mechanism described above.

In other words, not only would the democratisation of money through the use of Bitcoin fail to democratise capitalism, but it could also enhance powerful forms of regression.

Payment card security standards, composition and manufacturing process

Payment cards are made by the lamination of numerous layers of plastic and electronic components. In order to prevent the likelihood of fraud, cards are built with sophisticated security safeguards. These features include the card's magnetic stripe, chip, antenna, signature panel, payment scheme's hologram and account number.

Due to the high security environment of payment cards manufacturing, very little formal information is made available for the public. The information in this chapter refers to visits done personally to card manufacturing sites and to documents shared by card manufacturers directly to card issuers (banks).

Security standards

Plastic cards' systems are sustained by operational efficiency in growing IT modernisation. The magnetic stripe was one of the first security features of payment cards. Magnetic storage was known from World War II and computer data storage in the 1950s. The magnetic stripe of cards is capable of storing data by modifying the magnetism of tiny iron-based magnetic particles on a band attached to the card. The region covered in iron oxide particles can encode binary data to identify the card as authentic. It is challenging to know precisely what data is encoded on the strip because card producers are reluctant to reveal this for security reasons. However, since automatic teller machines (ATMs) keep cards that have expired, it is possible that the card's expiration date is one item recorded on the strip. Because banks do not reprint cards when information like the credit limit, address, phone number, or employer changes, it is unlikely that this information is stored on the stripe.

The signature panel on the card's back is another security design element. The purpose of the signature on a card is to show the owner's handwriting so that a fake signature on a receipt can be identified. The back panel of a stolen card is stamped with a fingerprint design that is difficult to duplicate and that will come off when the original signature is removed in order to deter thieves from removing the panel and adding their own signature. This design of the signature panel will also vanish if the signature is erased, leaving a white mark that immediately shows the card has been

manipulated. Below this panel, some card manufacturers put the term VOID, which is visible upon erasure.
Security holograms were invented by MasterCard in the early 1980s. They are now used on passports, sophisticated electronics, banknotes and payment cards. Cards' holograms are constructed from a number of layers of photographs taken from various angles and piled on top of one another. Therefore, even a small movement causes the image to appear to shift. The way the image is displayed on a card gives the impression that it is lifted above the surface of the card, giving it a three-dimensional appearance.

Holograms prevent counterfeiting since their many pictures can't be duplicated by a photocopier or scanned by an optical computer scanner. Additionally, holograms typically contain concealed images to offer instant authentication and validation.

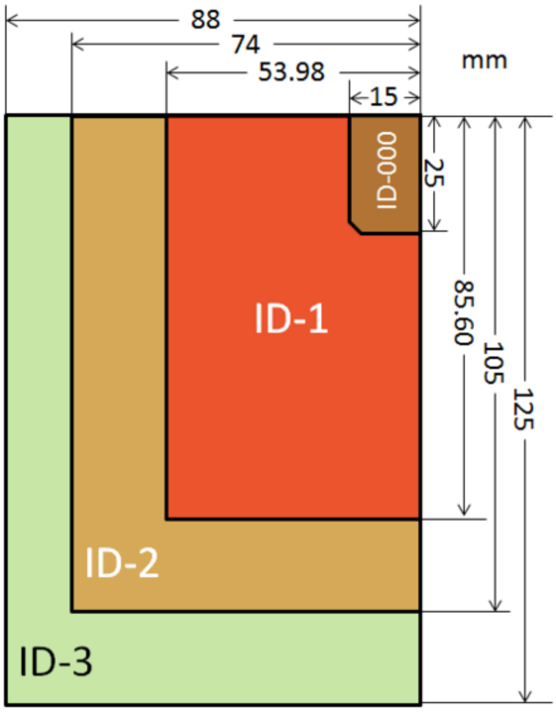
In 1994, the first EMV (Europay, Mastercard, and Visa) "chip" card was released. It took several years for the chip card to become widely used, since the card technology required businesses to alter their POS systems in order to support card transactions with the new chip. The EMV card has sophisticated security measures suitable to the biggest payment schemes' technologies (VISA, Mastercard, Europay). The vast majority of popular credit and debit cards in use today use EMV chips.

NFC (near-field communication) technology was introduced to payment cards in the late 2010s. The hardware needed for NFC in a card is the antenna, connected to the chip. To transfer payment information, this technology links two NFC-enabled devices that are only a few inches apart at most. The two-way encryption used in NFC payments is a key distinction factor of this technology, since it makes this method of payment more secure than only using an EMV chip or Magnetic stripe of a card.

When the card information is delivered to the payment terminal, it is encrypted. Additionally, transactions above a certain threshold defined by the bank need to be authorised by the cardholder by the insertion of a passcode. On mobile devices, the transaction needs to be authorised using a passcode, face ID, or a fingerprint. Once the transaction has been authenticated, the NFC terminal sends the transaction details along with a randomly generated one-time use code that is given to the merchant.
The one-time code used to deliver the encrypted payment information cannot be used more than once, which makes that information useless to be stolen. NFC payments do not occur accidentally and are challenging to hack because they require very close proximity to the terminal and biometric or multi-factor verification to proceed with the transaction.

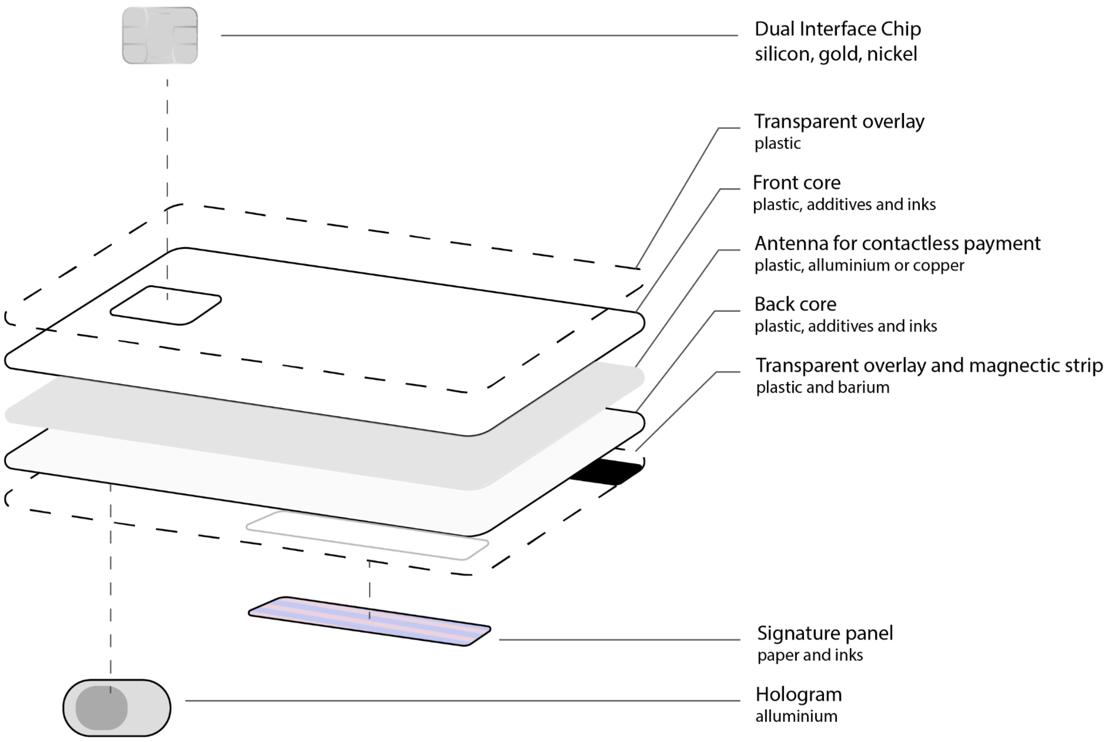
Card composition and manufacturing process

A payment card's size is defined by the ISO/IEC 7810 standard (145). This international standard defines four different card sizes, used typically for payment or identification cards.



ISO/IEC 7810 card sizes

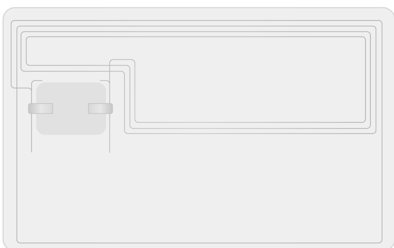
Payment cards have the size referring to ID-1, formatted at 85.6 x 53.98mm, with rounded corners with a radius of 2.88 to 3.48mm, and thickness from 0.25 to 0.76mm.
The standard also specifies requirements for the physical characteristics of cards, such as bending stiffness, toxicity, resistance to chemicals, durability, resistance to deterioration provenient from exposure to light and heat, and the card dimensional stability and warpage with temperature and humidity.



Composition of a payment card

Due to its flexible, durable and stress resistant properties, polyvinyl chloride acetate (PVCA) is commonly used for many plastic elements of payment cards. Both cores and overlay are most often made of PVCA. To give this resin the right appearance and consistency, opacifying agents, dyes, and plasticizers are combined with it.

The antenna element is in itself made by a metallic string, and in order to keep its shape, this antenna is pre-laminated with thin PVCA sheets and delivered to card manufacturers in sheets with multiple antennas prepared in the shape and size of payment cards.



Figurative image of a Pre-laminated antenna in the shape of a card

Surrounding the antenna are the front and back cores. Commonly, these are made in the form of PVCA sheets and made available for producers in various colours. The colour of the core will be visible in the edges of the finished card and is used as a base for the front and back designs. The inks used on the design of the card are printed on the card core.

Card samples with coloured cores

Card producers have access to a wide variety of inks and pigments, which enables cards to serve as effective communicators of brands and services.

There is a push to create more environment conscious techniques for printing, as the majority of inks used today still have a solvent base. The vapours from these solvent-based inks can be problematic during production. UV inks are more eco-friendly as they are 99.5% free of volatile organic compounds. Besides that, the inks dry faster than conventional silkscreen inks, resulting in faster production times and sharper printing. UV-cure inks are formulated to cure when exposed to controlled amounts of UV light, instead of by oxidation. They offer manufacturers more control over the screening procedure, and since their evaporating vapours cause less issues, they are better not only for the environment, but also for employees operating the machines.

On top of the card cores an overlay is placed. These are thinner lamination sheets, also commonly made of PVCA. The overlay sheets are the external layer of payment cards where the personalisation data of customers is later applied.

The manufacturing process of a payment card (146) consists of the following phases:

1. Plastic compounding and moulding
2. Printing
3. Lamination
4. Die cutting

1 - Plastic compounding and moulding

PVCA is melted, combined with various chemicals, and used to create the plastic for the core sheet. The blended mixture is then transferred to an extrusion moulding device that causes the molten plastic to be forced through a small, flat aperture known as a die.

The result is a sheet that is pulled along as it passes through a row of three rollers placed on top of one another as it leaves the die. These rollers have the role of preserving the sheet's flatness. The sheets then go through additional cooling devices before being divided into distinct smaller sheets, fit to the card printing machines.

The overlay laminate films are produced in a similar technique as the core material, but with a smaller die opening during the extrusion process.

2 - Printing

Text and images are printed on the card's plastic core. A number of typical silk screen methods are used for this.

- Offset inks: water based
  - Four colour process (CMYK)
  - Pantone colours
  - Suitable for thin lines and small details

- Silkscreen inks: oil based
  - Pantone colours
  - Metallic colours
  - Varnishes

Additionally, the overlay to be placed in the back of the card may go through further procedures in which magnetic ink is imprinted on it. The magnetic stripe could also be added using a hot stamping technique. The metal particles must be positioned on top of the overlay, as the magnetic stripe only works if the magnetic heads are very close to the surface of the card. The core is prepared for lamination after the printing process is finished.

3 - Lamination

The card's condition is protected by the lamination, which also strengthens the card. Sheets of core material, together with the overlay, are fed through a set of rollers in this procedure. The three pieces of plastic are kept together by suction while being transported to a tacking station.

The upper and bottom overlays are warmed by a pair of quartz infrared heat lamps at the tacking station. Reflectors on the rear of these lamps direct the radiant energy into a small area of the films, maximising a seamless bonding of the film to the core stock. Once thoroughly bonded, the laminate films are pressed by heated metal plates for three minutes, before being released for cutting.

4 - Die cutting

After lamination is done, the finished sheet of cards is cut and completed using die cutting techniques. Each sheet produced is then divided into 63 credit cards.
The card gets personalised with the cardholder's information throughout subsequent procedures. The completed cards are then ready for shipment, typically by being adhered with glue to a paper letter.

Key quality difficulties are connected with plastic compounding and ink colour matching. Ingredients must be carefully weighed, mixed, and blended at the appropriate temperature and shear conditions, as with any compounding procedure. Similarly, the moulding process must be closely watched in order to minimise flaws that could cause the cards to fracture or break.

Eco-innovation in payment cards

By 2024, only 7% of store payments in the UK will be made in cash (147), following a global trend in which cash payments account for fewer than 10% of shop transactions in nations such as Sweden, Canada, and Australia. However, even during the current era of global digitalisation, there were more than 25 billion payment cards in circulation in 2021, with this figure predicted to climb to more than 30 billion by 2025 (148).
Despite their convenience, physical payment cards have a significant environmental impact. Alternatives to materials and recycling techniques are available for card issuers.

Approximately six billion new plastic cards are produced and issued each year (149), with the majority of them made of PVCA. PVCA emits large amounts of toxic chemicals into the environment and is hazardous at all stages of its life cycle (manufacturing, usage, and disposal). Every year, over 5.7 million tonnes of plastic cards wind up in incinerators or landfills (150), where they take decades to degrade into microplastics and toxic residues. Subsequently, they will be consumed by wildlife and humans, potentially causing a variety of health difficulties as discussed in the chapter 'Plastics in the environment, its consequences to ecosystems and human health'.

Aside from the PVC, metal components, additives, and colours complicate the recycling process, but the absence of financial motivation ultimately defines the poor effort done to recycle this product. As a result, the plastic is either burnt, disposed of in landfills, or ends up in the oceans.

Alternatives to plastic payment cards

Digital payment solutions

Mobile wallets such as Apple's wallet, peer-to-peer digital payments such as PayPal or QR code based payments such as WeChat Pay, and crypto currencies are some payment methods that are increasingly common and that do not require a physical payment card.

Mobile wallets are the largest and most adaptable solution. It allows users to make payment transactions with physical POS at merchants. With a virtual card issued by a financial institution, the antenna of the user's smartphone serves as the NFC technology necessary to proceed with payments. Payments with virtual cards can be used in both physical shops with a smartphone, but also in online environments. Over 2.8 billion mobile wallets were in use by the end of 2020, and it is predicted that by 2025 more than one in two people will have used a virtual card (151).

Ecological payment cards

Many card issuers have started to distribute payment cards made of materials that impose lower impact on the environment.
The viable materials, which are suitable for ISO and security standards, for the production of payment cards are PVC, recycled PVC, ABS, PET, PLA and recycled PET (152).

Plastics amount to 14% of the overall impact of a debit card, with Distribution and logistics amounting to 34% and electronic components to 52% (153).

Several types of measures are possible to strive for a more sustainable Circular Economy:

- Material switch to less scarce and more environmentally friendly produced materials
- Recycled resources for the cards, e.g. rPVC, to save (some) fossil resources and fossil CO_2 Bio Based resources for the materials, e.g. PLA, to save fossil resources such as oil and fossil CO_2.
- Green power for the production of cards, saving fossil resources, CO_2 and other toxic emissions
- Recycling of cards, using different recycling options to save (some) fossil resources and fossil CO_2 Lifetime extension, saving proportionally all environmental and resource impacts
- Re-use, saving proportionally all environmental and resource impacts

The recycling and re-use of payment cards will herewith be judged out of scope. Considering costs, distribution impact and security issues related to both initiatives, their systems are today ineffective.

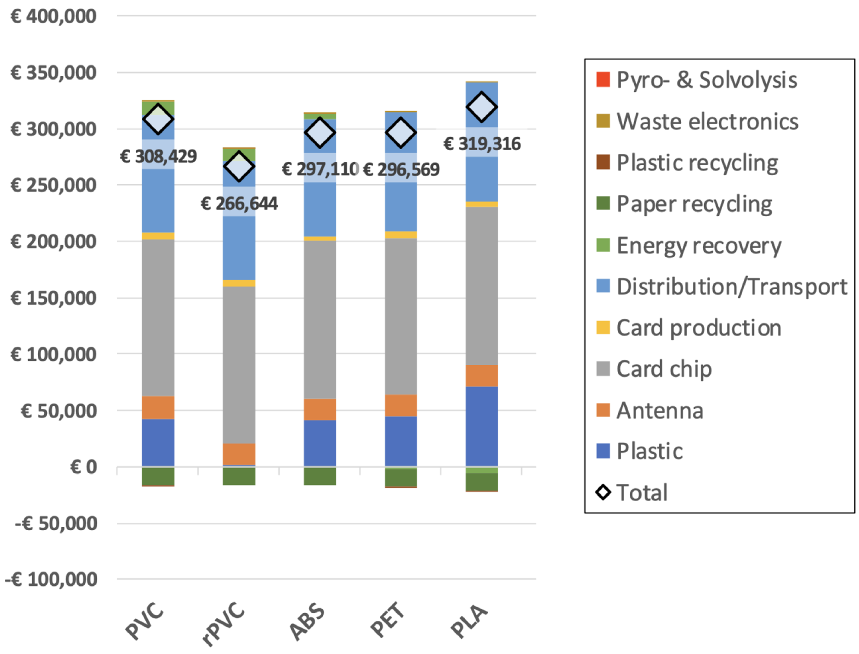
The environmental damage of payment cards can be expressed as per charts below:

Prices used to estimate costs for society

Impact category	Unit	IMPACT
Climate change	kg CO2 eq	0.057
Ozone depletion	kg CFC-11 eq	123
Terrestrial acidification	kg SO2 eq	8.12
Freshwater eutrophication	kg P eq	1.9
Marine eutrophication	kg N eq	3.11
Human toxicity	kg 1,4-DB eq	0.158
Photochemical oxidant formation	kg NMVOC	2.1
Particulate matter formation	kg PM10 eq	69
Terrestrial ecotoxicity	kg 1,4-DB eq	8.89
Freshwater ecotoxicity	kg 1,4-DB eq	0.0369
Marine ecotoxicity	kg 1,4-DB eq	0.00756
Ionising radiation	kBq U235 eq	0.0473
Agricultural land occupation	m2a	0.026
Urban land occupation	m2a	0.026
Natural land transformation	m2	0
Water depletion	m3	2.77
Metal depletion	kg Fe eq	0.09
Fossil depletion	kg oil eq	0.2

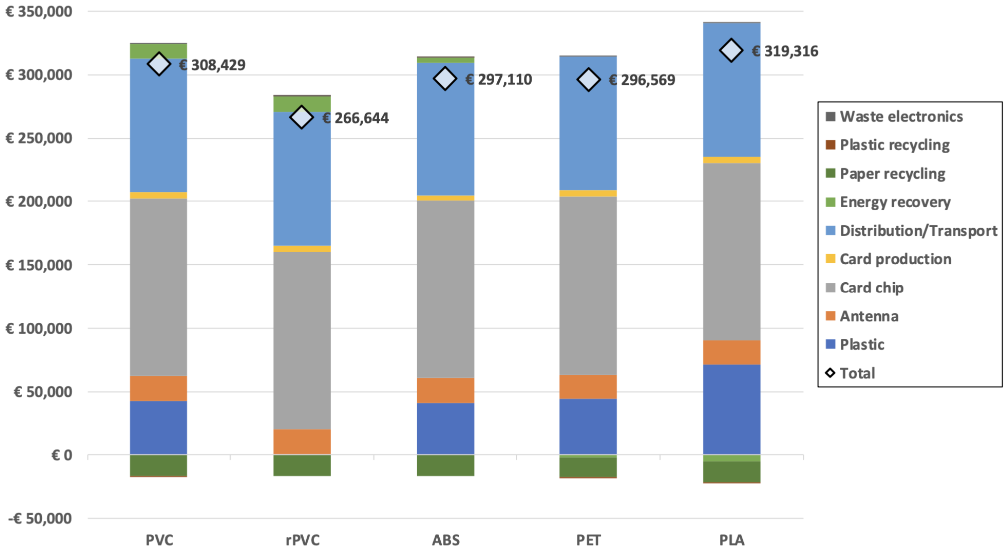
Source: TNO report for Betaalverening Nederland (2019)

Contribution of card elements, in euro



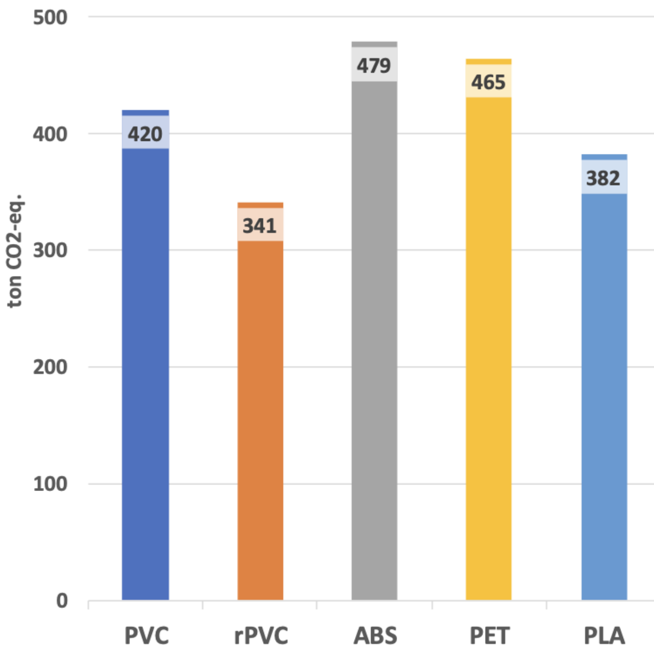
Source: TNO report for Betaalverening Nederland (2019)

Contribution of card elements for Energy recovery scenario



Source: TNO report for Betaalverening Nederland (2019)

Contribution to Climate Change



Source: TNO report for Betaalverening Nederland (2019)

Different materials such as PVC, PET, ABS have a comparable contribution to the total impact. Because of its biobased origin, a PLA card has the highest energy recovery benefit, but still the highest net material impact. PLA's higher impact is due to plant protection products, fertilisers and land use.

Using recycled (r)PVC to produce cards gives the best performance as it reduces the contribution of the plastic to 2% of the value for virgin PVC. A total lower impact of up to 14% can be reached by the use of rPVC for payment card bodies.

Additionally, the combination of a switch of card body material to rPVC with strictly regulated suppliers that make use of green energy can add up to a payment card which is 25% less impactful for the environment.

Conclusion and recommendations for card issuers

For many years, the world’s economy has been dominated by a take - make - dispose paradigm, the ‘linear economy’, in which our planet’s resources are perceived as endless. Plastic products are widely used in society with little, though increasing, conscious effort to lessen their consumption. As a result, plastic pollution has become one of the world’s most pressing environmental issues. Plastics remain today the workhorse material of the modern economy and ubiquitous in our everyday lives. Despite growing awareness about this issue, plastic production is expected to continue to increase in volume (154).

Investors, regulators, and banks had already begun connecting sustainability to their corporate goals and actions prior to the Covid-19 pandemic, in line with the United Nations Environment Programme Finance Initiative (UNEP FI - November 2018), which had just released the first iteration of its Principles for Responsible Banking. These guidelines offer a worldwide framework and roadmap and are based on United Nations’ 17 Sustainable Development Goals (SDGs).

The pandemic turned out to be a crucial turning point. Customers started to think more thoroughly about ethical and environmental sustainability issues. In both developed and developing nations, eco-consumerism is becoming a force to be reckoned with, according to a recent global survey from PWC (155).

- In the six months previous to the survey, 58% of Millennials (ages 27 to 32) said they have become more environmentally conscious.
- 60% of consumers between the ages of 23 and 26 make a conscious decision to only make purchases from businesses that value and support environmental protection.

Today's consumers expect brands to play a positive role in advancing socio-environmental projects, and will switch products or services if they feel a brand does not align with their beliefs.

Payment cards made of rPVC or other less harmful materials are a practical demonstration of the organisation's commitment to pursuing a sustainability agenda and to engaging with clients in a positive manner regarding the climate crisis, even though they are not the primary cause of a bank's impact on the environment and society. Banks that want to live up to the "principles for responsible banking" and lead by example should consider the implementation of ecological payment cards.

A bank's dedication to a more responsible and sustainable future can be demonstrated in a direct and very useful way by offering eco-friendly payment cards. Of course, eco payment cards are not a magic fix to financial institutions' environmental impact, and it shouldn't be presented in that way. However, when included in a larger Corporate Social Responsibility (CSR) strategy, replacing the card's body material is an important step to demonstrate the institution's intention to become more sustainable come to practice.

While a significant first step, producing cards with more environmentally friendly materials is just the beginning. If issuers want to genuinely enable long-lasting changes and firmly demonstrate their green credentials, they must also take into account the production, personalization, logistics, and issuance procedures that are involved. This entails collaborating with card producers that make proactive practical efforts to lessen their carbon footprint and that can offer issuers guidance and best practices to improve the environmental performance of their whole payment card issuance strategy.

The need for evidence-based certifications for ecological payment cards is also relevant to making additional progress in the field. Further iterations on definitions of what materials and processes actually qualify as "eco-friendly" need to be periodically reviewed, resulting in more specific requirement criteria in respect to cards (i.e. specific percentage of recycled material used in rPVC).

It is evident that reforming business models, behaviours, and consumption models are the only way to halt the environmental regress caused by the linear economy, and that rethinking the use of plastics in the future is one of the major challenges facing society in the twenty-first century. Changes to the material composition of consumer goods, and improvements on the recycling industry will reduce the need for landfill areas, oil consumption, energy use and toxic emissions, which will then result in positive effects to protecting the environment and hopefully keeping the earth in habitual conditions to humans. The worldwide call for sustainable solutions, prompted by climate change, is heard from powerful organisations like the UN down to ordinary customers and individuals, underscoring the importance of such improvements. The linear economy model is being challenged and slowly but surely replaced by a circular way of thinking.

Corporations that produce physical products and commodities should change ways of producing, leading to the circular economy. Eco-innovative payment cards are one tangible symbol of banks' transition to a greener future, but these financial institutions' real power to drive positive environmental change in several industries lie in making their loan portfolios greener. Therefore, a combination of the implementation of eco-innovative cards with forward-looking CSR strategies are crucial for the genuine sustainable transition of banks.

References

1. MacDonald, Jay. "Are credit cards recyclable? It's complicated." CreditCards.com, 8 November 2017, https://www.creditcards.com/education/are-credit-cards-recyclable/. Accessed 15 August 2022.
2. "Pollution Facts | PlasticOceans.org/the-facts." Plastic Oceans International, https://plasticoceans.org/the-facts/. Accessed 17 August 2022.
3. Barone, Adam. "Bank Definition: How Does Banking Work?" Investopedia, https://www.investopedia.com/terms/b/bank.asp. Accessed 17 August 2022.
4. "Sustainability | United Nations." the United Nations, https://www.un.org/en/academic-impact/sustainability. Accessed 17 August 2022.
5. "Our Common Future: Report of the World Commission on Environment and Development." Sustainable Development Goals, http://www.un-documents.net/our-common-future.pdf. Accessed 17 August 2022.
6. "Resolution adopted by the General Assembly on 25 September 2015" the United Nations, https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E. Accessed 17 August 2022.
7. "The Sustainable Development Agenda - United Nations Sustainable Development." the United Nations, 26 July 2022, https://www.un.org/sustainabledevelopment/development-agenda/. Accessed 17 August 2022.
8. Undocs.org, https://undocs.org/en/A/HLPF/2019/l.1. Accessed 29 August 2022.
9. "Decade of Action - United Nations Sustainable Development." the United Nations, 13 August 2020, https://www.un.org/sustainabledevelopment/decade-of-action/. Accessed 17 August 2022.
10. "Overview of sustainable finance." Finance, https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/overview-sustainable-finance_en. Accessed 29 August 2022.
11. "Principles for Responsible Banking – United Nations Environment – Finance Initiative." UNEP Finance Initiative, https://www.unepfi.org/banking/bankingprinciples/. Accessed 17 August 2022.
12. "Impact Analysis – United Nations Environment – Finance Initiative." UNEP Finance Initiative, https://www.unepfi.org/banking/bankingprinciples/resources-for-implementation/impact-analysis/. Accessed 17 August 2022.
13. guide, step. "Target-Setting – United Nations Environment – Finance Initiative." UNEP Finance Initiative, https://www.unepfi.org/banking/bankingprinciples/resources-for-implementation/target-setting/. Accessed 17 August 2022.
14. "Reporting – United Nations Environment – Finance Initiative." UNEP Finance Initiative, https://www.unepfi.org/banking/bankingprinciples/resources-for-implementation/reporting/. Accessed 17 August 2022.
15. "Our own operations | ING." ING Bank, https://www.ing.com/Sustainability/Our-own-operations.htm. Accessed 17 August 2022.
16. "Environmental performance | ING." ING Bank, https://www.ing.com/Sustainability/Our-own-operations/Environmental-performance.htm. Accessed 17 August 2022.
17. "The Ten Principles." UN Global Compact, https://www.unglobalcompact.org/what-is-gc/mission/principles. Accessed 17 August 2022.
18. "titel van uitspraak." titel van uitspraak - Stichting Reclame Code, 26 August 2021, https://www.reclamecode.nl/uitspraken/resultaten/vervoer-2021-00190/304997/. Accessed 17 August 2022.
19. "Characterization of Polymers" in EPST 1st ed., Vol. 3, pp. 611–631, by W. R. Sorenson, Continental Oil Co.; in EPSE 2nd ed., Vol. 3, pp. 290–327, by W. J. Freeman, Hercules, Inc. https://onlinelibrary-wiley-com.ezproxy.biblio.polito.it/doi/10.1002/0471440264.pst048 Accessed 14 August 2022.
20. Riva, Joseph P. "petroleum | Energy, Products, & Facts." Britannica, https://www.britannica.com/science/petroleum. Accessed 29 August 2022.
21. Hale, Rebecca. "Petroleum." National Geographic Society, 27 July 2022, https://www.nationalgeographic.org/encyclopedia/petroleum/12th-grade/. Accessed 29 August 2022.
22. "Addition Polymerization" in EPST 1st ed., Vol. 1, pp. 444–445; in EPSE 2nd ed., Vol. 1, pp. 470–471. https://onlinelibrary-wiley-com.ezproxy.biblio.polito.it/doi/10.1002/0471440264.pst057. Accessed 14 August 2022
23. Baheti, Payal. How Is Plastic Made? A Simple Step-By-Step Explanation, https://www.bpf.co.uk/plastipedia/how-is-plastic-made.aspx. Accessed 29 August 2022.
24. "plastic - The processing and fabrication of plastics." Britannica, https://www.britannica.com/science/plastic/The-processing-and-fabrication-of-plastics#ref82473. Accessed 29 August 2022.
25. "Calendering | Find suppliers, processes & material." Manufacturing Guide, https://www.manufacturingguide.com/en/calendering. Accessed 29 August 2022.
26. Brown, Laurie M. "Alexander Parkes | British chemist." Britannica, https://www.britannica.com/biography/Alexander-Parkes. Accessed 29 August 2022.
27. "major industrial polymers - Cellulose nitrate." Britannica, https://www.britannica.com/topic/industrial-polymers-468698/Cellulose-nitrate. Accessed 29 August 2022.
28. "Bakelite First Synthetic Plastic - National Historic Chemical Landmark." American Chemical Society, https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/bakelite.html. Accessed 29 August 2022.
29. "polymer - Synthetic polymers." Britannica, 8 August 2022, https://www.britannica.com/science/polymer/Synthetic-polymers. Accessed 29 August 2022.
30. "Waldo Semon | American chemist." Britannica, https://www.britannica.com/biography/Waldo-Semon. Accessed 29 August 2022.
31. "Cos'è la plastica e come si produce." Riciclo plastica, https://ricicloplastica.it/la-plastica/. Accessed 29 August 2022.
32. "Storia della plastica." Plasticalike, http://www.plasticalike.it/storia-della-plastica/ Accessed 29 August 2022.

33. *“Cumulative global production of plastics.” Our World in Data, https://ourworldindata.org/grapher/cumulative-global-plastics. Accessed 29 August 2022.*
34. *https://www.sciencedirect.com/science/article/pii/B9780444636072000034. Accessed 29 August 2022.*
35. *Brunnermeier, Markus K. THE RESILIENT SOCIETY, https://bcf.princeton.edu/wp-content/uploads/sites/3/2021/09/The-Resilient-Society-FirstPages.pdf. Accessed 29 August 2022.*
36. *“Plastic & Health.” Centre for International Environmental Law, https://www.ciel.org/plasticandhealth/. Accessed 29 August 2022.*
37. *“Natural Gas Flaring, Processing, and Transportation.” Union of Concerned Scientists, 19 June 2014, https://www.ucsusa.org/resources/natural-gas-flaring-processing-and-transportation. Accessed 29 August 2022.*
38. *Jake Hays & Seth B.C. Shonkoff, Toward an Understanding of the Environmental and Public Health Impacts of Unconventional Natural Gas Development: A Categorical Assessment of the Peer-Reviewed Scientific Literature, 2009-2015, 11(4) PLoS ONE (2016) https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0154164 Accessed 29 August 2022*
39. *“Particulate Matter (PM) Pollution | US EPA.” Environmental Protection Agency, 7 July 2022, https://www.epa.gov/pm-pollution. Accessed 29 August 2022.*
40. *“Fumes Across the Fence-Line.” Clean Air Task Force, 1 November 2017, https://www.catf.us/wp-content/uploads/2017/11/CATF_Pub_FumesAcrossTheFenceLine.pdf. Accessed 29 August 2022.*
41. *“Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States.” Environmental Protection Agency, https://www.epa.gov/sites/default/files/2016-12/documents/hfdwa_executive_summary.pdf. Accessed 29 August 2022.*
42. *Hays, Brooks. “Study finds 6600 fracking spills in four states over 10 years.” UPI, 21 February 2017, https://www.upi.com/Science_News/2017/02/21/Study-finds-6600-fracking-spills-in-four-states-over-10-years/5611487691909/. Accessed 29 August 2022.*
43. *“INGAA Website - North American Midstream Infrastructure Through 2035 - A Secure Energy Future Report.” INGAA, https://www.ingaa.org/Foundation/Foundation%E2%80%90Reports/Studies/14904/14889.aspx. Accessed 29 August 2022.*
44. *Soraghan, Mike. “Article | Flow lines cited in more than 7K spills.” POLITICO Pro, 16 May 2017, https://subscriber.politicopro.com/article/eenews/1060054568. Accessed 29 August 2022.*
45. *PennFuture | Home, https://www.pennfuture.org/Files/Admin/ng-pipelines.pdf. Accessed 29 August 2022.*
46. *See Nels Johnson, Tamara Gagnolet, Rachel Ralls & Jessica Stevens, The Nature Conservancy – Pa. Chapter, Natural Gas Pipelines: Excerpt from Report 2 of the Pennsylvania Energy Impacts Assessment (2011)*
47. *“Pollutants and Sources | Technology Transfer Network Air Toxics Web site | US EPA.” Environmental Protection Agency, 26 September 2018, https://www3.epa.gov/airtoxics/pollsour.html. Accessed 29 August 2022.*
48. *“Plastic and health: the Hidden Costs of a Plastic Planet” Ciel, February 2019. https://www.ciel.org/wp-content/uploads/2019/02/Plastic-and-Health-The-Hidden-Costs-of-a-Plastic-Planet-February-2019.pdf. Accessed 29 August 2022.*
49. *“White Paper - Front Matter Template.” Union of Concerned Scientists, 23 August 2018, https://www.ucsusa.org/sites/default/files/attach/2018/08/impact-chemical-facilities-on-environmental-justice-communities-ucs-2018.pdf. Accessed 29 August 2022.*
50. *Moure, Rafael. “BP America Refinery Explosion | CSB.” Chemical Safety Board, https://www.csb.gov/bp-america-refinery-explosion/. Accessed 29 August 2022.*
51. *“Workers' Rights Archives – Centre for Public Integrity.” Centre for Public Integrity, https://publicintegrity.org/workers-rights/. Accessed 29 August 2022.*
52. *See Roland Geyer, Jenna R. Jambeck & Kara Lavender Law, Production, Use and Fate of All Plastics Ever Made, 3(7) Sci. Advances 1 (2017). https://www.science.org/doi/10.1126/sciadv.1700782 Accessed 29 August 2022.*
53. *See Delilah Lithner, Åke Larsson, & Göran Dave, Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition, 409(18) Sci. of The Total Env’t 3309, 3309-24 (2011)*
54. *See Thomas Roy Crompton, Additive Migration from Plastics Into Foods: A Guide for Analytical Chemists (2007)*
55. *See Stephanie L. Wright & Frank J. Kelly, Plastic and Human Health: A Micro Issue?, 51(12) Envtl. Sci. & Tech. 6634, 6634-47 (2017) https://pubs.acs.org/doi/10.1021/acs.est.7b00423 Accessed 29 August 2022.*
56. *Carbery M, O'Connor W, Palanisami T. Trophic transfer of microplastics and mixed contaminants in the marine food web and implications for human health. Environ Int. 2018 Jun;115:400-409. doi: 10.1016/j.envint.2018.03.007. Epub 2018 Apr 10. PMID: 29653694.*
57. *Soto, H. “Migration of bisphenol A (BPA) from can coatings into a fatty-food simulant and tuna fish.” PubMed, https://pubmed.ncbi.nlm.nih.gov/16192075/. Accessed 29 August 2022.*
58. *Yilmaz B, Terekeci H, Sandal S, Kelestimur F. Endocrine disrupting chemicals: exposure, effects on human health, mechanism of action, models for testing and strategies for prevention. Rev Endocr Metab Disord. (2020)*
59. *Jensen S., Lange R., Berge G., Palmork K. H. and Renberg L. 1975On the chemistry of EDC-tar and its biological significance in the seaProc. R. Soc. Lond. B.189333–346*
60. *See Luz Claudio, Our Food: Packaging and Public Health, 120(6) Envtl. Health Persp. A232, a232-a237 (2012), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3385451; see also, Thomas G. Neltner et al. Data gaps in toxicity testing of chemicals allowed in food in the United States, 42 Reprod. Toxicology 85, 95-94 (2013), https://www.ncbi.nlm.nih.gov/pubmed/23954440 Accessed on 29 August 2022.*
61. *See UNEP, Solid Waste Management: Sound practices – Incineration, http://www.unep.or.jp/ietc/ESTdir/Pub/MSW/sp/SP5/SP5_4.asp. Accessed 29 August 2022.*
62. *See Yibo Zhang et al., Leaching Characteristics of Trace Elements from Municipal Solid Waste Incineration Fly Ash, Geotechnical Special Publ’n 168, 168-78 (2016); IPEN, After Incineration: The Toxic Ash Problem (2005), http://ipen.org/sites/default/files/documents/After_incineration_the_toxic_ash_problem_2015.pdf. Accessed 29 August 2022.*

63. See UNEP, Waste-to-Energy Incineration. https://wedocs.unep.org/bitstream/handle/20.500.11822/32795/WtEI.pdf?sequence=1&isAllowed=y. Accessed 29 August 2022.
64. See Bart Ostro et al., Associations of Mortality with Long-term Exposures to Fine and Ultrafine Particles, Species and Sources: Results from the California Teachers Study Cohort, 123(6) Envtl. Health Persp. 549, 549-56 (2015), https://www.ncbi.nlm.nih.gov/pubmed/25633926. Accessed 29 August 2022
65. See National Research Council (US) Committee on Health Effects of Waste Incineration, Waste Incineration & Public Health (2000), https://www.ncbi.nlm.nih.gov/books/NBK233633. Accessed 29 August 2022.
66. See Health Effects Institute, the Institute for Health Metrics and Evaluation & University of British Colombia, State of Global Air 2017: A Special Report on Global Exposure to Air Pollution and Its Disease Burden (2017), https://www.stateofglobalair.org/sites/default/files/SoGA2017_report.pdf. Accessed 29 August 2022.
67. See Lara Schwarz, Tarik Benmarhnia & Lucie Laurian, Social Inequalities Related to Hazardous Incinerator Emissions: An Additional Level of Environmental Injustice, 8(6) Envtl. Just. 213, 213-19 (2015); Marco Martuzzi, Francesco Mitis & Francesco Forastiere, Inequalities, inequities, environmental justice in waste management and health, 21(6) The Eur. J. of Pub. Health 21, 21-26 (2010); Ana Isabel Baptista & Kumar Kartik Amarnath, Garbage, Power, and Environmental Justice: The Clean Power Plan Rule, 403 Wm. & Mary Envtl. L. & Pol'y Rev. 41 (2017).
68. See Joerg Römbke et al., Ecotoxicological Characterisation of 12 Incineration Ashes using 6 Laboratory Tests, 29(9) Waste Mgmt. 2475, 2475-82 (2009), https://doi.org/10.1016/j.wasman.2009.03.032. Accessed 29 August 2022.
69. See Joerg Römbke et al., Ecotoxicological Characterisation of 12 Incineration Ashes using 6 Laboratory Tests, 29(9) Waste Mgmt. 2475, 2475-82 (2009), https://doi.org/10.1016/j.wasman.2009.03.032. Accessed 29 August 2022.
70. See UNEP, Solid Waste Management: Sound practices—Incineration, supra note 234.
71. See Yibo Zhang et al., Leaching Characteristics of Trace Elements from Municipal Solid Waste Incineration Fly Ash, Geotechnical Special Publ'n 168, 168-78 (2016); IPEN, After Incineration: The Toxic Ash Problem (2005), http://ipen.org/sites/default/files/documents/After_incineration_the_toxic_ash_problem_2015.pdf. Accessed 29 August 2022.
72. See Aneeta Mary Joseph et al., The Use of Municipal Solid Waste Incineration Ash in Various Building Materials: A Belgian Point of View, 11(1) Materials 141 (2018), https://www.ncbi.nlm.nih.gov/pubmed/29337887. Accessed 29 August 2022.
73. See Sanae Chiba et al., Human footprint in the abyss: 30 year records of deep-sea plastic debris, 96 Marine Pol'y 204, 204-12 (2018), https://doi.org/10.1016/j.marpol.2018.03.022. Accessed 29 August 2022.
74. See Jenna Jambeck et al., Plastic waste inputs from land into the ocean, 347(6223) Sci. 768, 768–71 (2015), http://science.sciencemag.org/content/347/6223/768. Accessed 29 August 2022.
75. See Marcus Eriksen et al., Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea, 9(12) PLoS ONE (2014), https://doi.org/10.1371/journal.pone.0111913. Accessed 29 August 2022.
76. See Bianca Unger et al., Large Amounts of Marine Debris found in Sperm Whales Stranded along the North Sea coast in Early 2016, 112(1-2) Marine Pollution Bull. 134, 134-41 (2016), https://www.ncbi.nlm.nih.gov/pubmed/27539635. Accessed 29 August 2022.
77. See David Santillo, Kathryn A. Miller & Paul Johnston, Microplastics as Contaminants in Commercially Important Seafood Species, 13 Integrated Envtl. Assessment & Mgmt. 516, 516-21 (2017), https://www.ncbi.nlm.nih.gov/pubmed/28440928. Accessed 29 August 2022.
78. See Sharareh Dehghani, Farid Moore & Razegheh Akhbarizadeh, Microplastic Pollution in Deposited Urban Dust, Tehran metropolis, Iran, 24(25) Envtl. Sci. Pollution Res. 20360, 20360–71 (2017), https://www.ncbi.nlm.nih.gov/pubmed/28707239.Accessed 29 August 2022.
79. See Rachid Dris et al., Microplastics contamination in an urban area: A case study in Greater Paris, 12(5) Envtl. Chemistry 592 (2015), https://doi.org/10.1071/EN14167. Accessed 29 August 2022.
80. See Liqi Cai et al., Characteristics of microplastics in the atmospheric fallout from Dongguan city, China: preliminary research and first evidence, 24(32) Envtl. Sci. & Pollution Res. 24928 (2017), https://www.ncbi.nlm.nih.gov/pubmed/28918553. Accessed 29 August 2022.
81. Press Release, United European Gastroenterology, UEG Week: Microplastics discovered in human stools across the globe in 'first study of its kind' (Oct. 23, 2018), https://www.ueg.eu/press/releases/ueg-press-release/article/ueg-week-microplastics-discovered-inhuman-stools-across-the-globe-in-first-studyof-its-kind. Accessed 29 August 2022.
82. See Maddison Carbery, Wayne O'Connor & Palanisami Thavamani, Trophic Transfer of Microplastics and Mixed Contaminants in the Marine Food Web and Implications for Human Health, 115 Env't Int'l 400, 400-09 (2018), https://www.ncbi.nlm.nih.gov/pubmed/29653694. Accessed 29 August 2022.
83. See Tamara S. Galloway, Matthew Cole & Ceri Lewis, Interactions of microplastic debris throughout the marine ecosystem, 1(5) Nature Ecology & Evolution 116 (2017), https://www.ncbi.nlm.nih.gov/pubmed/28812686. Accessed 29 August 2022.
84. See Stephanie Borrell et al., Opinion, Why we need an international agreement on marine plastic pollution, 114(38) P.N.A.S. USA 9994, 9994-97 (2017), https://www.pnas.org/content/114/38/9994. Accessed 29 August 2022.
85. See Boris Worm et al., Plastic as a Persistent Marine Pollutant, 42(1) Ann. Rev. of Env't & Resources 1, 1-26 (2017), https://doi.org/10.1146/annurev-environ-102016-060700. Accessed 29 August 2022.
86. See Editorial, Microplastics and human health – an urgent problem, 1(7) The Lancet Planetary Health e254 (Oct. 2017), https://doi.org/10.1016/S2542-5196(17)30121-3. Accessed 29 August 2022.
87. See Amy V. Kontrick, Microplastics and Human Health: Our Great Future to Think About Now, 14(2) J. of Med. Tech. 117, 117-19 (2018), https://www.ncbi.nlm.nih.gov/pubmed/29687221. Accessed 29 August 2022.
88. See Eur. Food Safety Authority (EFSA) Panel on Contaminants in the Food Chain, Statement on the presence of microplastics and nanoplastics in food, with particular focus on seafood, 14(6) Eur. Food Safety Auth. J. 4501 (2016), https://doi.org/10.2903/j.efsa.2016.4501. Accessed 29 August 2022.
89. See Stephanie L. Wright & Frank J. Kelly, Plastic and Human Health: A Micro Issue?, 51(12) Envtl. Sci. & Tech. 6634, 6634-47 (2017), https://pubs.acs.org/doi/10.1021/acs.est.7b00423. Accessed 29 August 2022.

90. See Sarah C. Gall & Richard C. Thompson, The impact of debris on marine life, 92(1-2) Marine Pollution Bull. 170, 170-79 (2015), https://doi.org/10.1016/j.marpolbul.2014.12.041. Accessed 29 August 2022.
91. See David Santillo, Kathryn A. Miller & Paul Johnston, Microplastics as Contaminants in Commercially Important Seafood Species, 13 Integrated Envtl. Assessment & Mgmt. 516, 516-21 (2017), https://www.ncbi.nlm.nih.gov/pubmed/28440928. Accessed 29 August 2022.
92. See Christoph D. Rummel et al., Plastic Ingestion by Pelagic and Demersal Fish from the North Sea and Baltic Sea, 102(1) Marine Pollution Bull. 134, 134-41 (2016), https://doi.org/10.1016/j.marpolbul.2015.11.043. Accessed 29 August 2022.
93. See France Collard et al., Microplastics in livers of European anchovies (Engraulis encrasicolus, L.), 229 Envtl. Pollution 1000, 1000-05 (2017), https://www.ncbi.nlm.nih.gov/pubmed/28768577. Accessed 29 August 2022.
94. See Jiana Li et al., Microplastics in mussels sampled from coastal waters and supermarkets in the United Kingdom, 241 Envtl. Pollution 35, 35-44 (2018), https://doi.org/10.1016/j.envpol.2018.05.038. Accessed 29 August 2022.
95. See Ali Karami et al., Microplastics in eviscerated flesh and excised organs of dried fish, 7 Sci. Rep. (2017), https://www.nature.com/articles/s41598-017-05828-6. Accessed 29 August 2022.
96. See Kasper B. Sundbæk et al., Sorption of fluorescent polystyrene microplastic particles to edible seaweed Fucus vesiculosus, 30(5) J. of Applied Phycology 2923, 2923-27 (2018), https://link.springer.com/article/10.1007/s10811-018-1472-8. Accessed 29 August 2022.
97. See Dongqi Yang et al., Microplastic Pollution in Table Salt from China, 49(22) Envtl. Sci. & Tech. 13622, 13622–627 (2015), https://www.ncbi.nlm.nih.gov/pubmed/26486565. Accessed 29 August 2022.
98. See Maria E. Iñiguez, Juan A. Conesa & Andres Fullana, Microplastics in Spanish table salt, 7 Sci. Rep. (2017), https://www.nature.com/articles/s41598-017-09128-x. Accessed 29 August 2022.
99. See Ali Karami, Abolfazl Golieskardi, Cheng Keong Choo, Vincent Larat, Tamara S. Galloway & Babak Salamatinia, The presence of microplastics in commercial salts from different countries, 7 Sci. Rep. (2017), https://www.nature.com/articles/srep46173. Accessed 29 August 2022.
100. See Anderson Abel de Souza Machado et al., Microplastics as an emerging threat to terrestrial ecosystems, 24(4) Global Change Biology 1405, 1405-16 (2018), https://www.ncbi.nlm.nih.gov/pubmed/29245177. Accessed 29 August 2022.
101. See Barbara E. Oßmann et al., Small-sized microplastics and pigmented particles in bottled mineral water, 141 Water Res. 307, 307-16 (2018), https://doi.org/10.1016/j.watres.2018.05.027. Accessed 29 August 2022.
102. See Gerd Liebezeit & Elisabeth Liebezeit, Synthetic Particles as Contaminants in German beers, 31(9) Food Additives & Contaminants Part A: Chemistry, Analysis, Control, Exposure & Risk Assessment 1574, 1574-78 (2014), https://doi.org/10.1080/19440049.2014.945099. Accessed 29 August 2022.
103. Mary Kosuth, Sherri A. Mason & Elizabeth V. Wattenberg, Anthropogenic contamination of tap water, beer, and sea salt (2018)https://doi.org/10.1371/journal.pone.0194970. Accessed 29 August 2022.
104. See Matthew Cole et al., Microplastic Ingestion by Zooplankton, 47(12) Envtl. Sci. & Tech. 6646, 6646-55 (2013), https://www.ncbi.nlm.nih.gov/pubmed/23692270 Accessed 29 August 2022.
105. See Outi Setälä, Vivi Fleming-Lehtinen & Maiju Lehtiniemi, Ingestion and transfer of microplastics in the planktonic food web, 185 Envtl. Pollution 77, 77-83 (2014), https://doi.org/10.1016/j.envpol.2013.10.013. Accessed 29 August 2022.
106. See Paul Farrell & Kathryn Nelson, Trophic Level Transfer of Microplastic: Mytilus edulis (L.) to Carcinus maenas (L.), 177 Envtl. Pollution 1, 1-3 (2013), https://doi.org/10.1016/j.envpol.2013.01.046. Accessed 29 August 2022.
107. See Yooeun Chae et al., Trophic Transfer and Individual Impact of Nano-sized Polystyrene in a Four-species Freshwater Food Chain, 8 Sci. Rep. (2018), https://www.nature.com/articles/s41598-017-18849-y. Accessed 29 August 2022.
108. See Frederic Gallo et al., Marine Litter Plastics and Microplastics and their Toxic Chemicals Component: the Need for Urgent Preventive Measures, 30(13) Envtl. Sci. Eur. 13 (2018), https://www.ncbi.nlm.nih.gov/pubmed/29721401. Accessed 29 August 2022.
109. See Yongfeng Deng et al., Tissue accumulation of microplastics in mice and biomarker responses suggest widespread health risks of exposure, 7 Sci. Rep. (2017), https://www.nature.com/articles/srep46687. Accessed 29 August 2022.
110. See Dris et al., Microplastics contamination in an urban area: A case study in Greater Paris
111. See Liqi Cai et al., Characteristic of microplastics in the atmospheric fallout from Dongguan city, China: preliminary research and first evidence, 24(32) Envtl. Sci. & Pollution Res. 24928 (2017), https://www.ncbi.nlm.nih.gov/pubmed/28918553. Accessed 29 August 2022.
112. See Subrahmaniyan Kasirajan & Mathieu Ngouajio, Polyethylene and Biodegradable Mulches for Agricultural Applications: A Review, 32(2) Agronomy for Sustainable Dev. 501, 501-29 (2012), https://doi.org/10.1007/s13593-011-0068-3. Accessed 29 August 2022.
113. See Robyne Williams, Flocking, Love to Know, https://fashion-history.lovetoknow.com/fabrics-fibers/flocking. Accessed 29 August 2022.
114. See Joana Correia Prata, Airborne Microplastics: Consequences to Human Health?, 234 Envtl. Pollution 115, 116 (2018), https://doi.org/10.1016/j.envpol.2017.11.043. Accessed 29 August 2022.
115. See Robyne Williams, Flocking, Love to Know, https://fashion-history.lovetoknow.com/fabrics-fibers/flocking. Accessed 29 August 2022.
116. See Matthias C. Rillig, Microplastic in Terrestrial Ecosystems and the Soil?, 46(12) Envtl. Sci. & Tech. 6453, 6453-54 (2012).
117. See Sarah Piehl et al., Identification and Quantification of Macro- and Microplastics on an Agricultural Farmland, 8 Sci. Rep. (2018), https://www.nature.com/articles/s41598-018-36172-y. Accessed 29 August 2022.
118. See Alice A. Horton et al., Microplastics in Freshwater and Terrestrial Environments: Evaluating the Current Understanding to Identify the Knowledge Gaps and Future Research Priorities, 586 Sci. of The Total Env't 127, 127-41 (2017), https://www.ncbi.nlm.nih.gov/pubmed/28169032. Accessed 29 August 2022.
119. See Sherri A. Mason et al., Microplastic Pollution is Widely Detected in U.S. Municipal Wastewater Treatment Plant Effluent, 218 Envtl. Pollution 1045, 1045-1054 (2016), https://www.ncbi.nlm.nih.gov/pubmed/27574803. Accessed 29 August 2022.

120. *See Julia Talvitie et al., How well is microlitter purified from wastewater?—A detailed study on the stepwise removal of microlitter in a tertiary level wastewater treatment plant, 109 Water Res. 164, 164-72 (2017), https://doi.org/10.1016/j.watres.2016.11.046. Accessed 29 August 2022.*
121. *See Anderson Abel de Souza Machado et al., Microplastics as an emerging threat to terrestrial ecosystems, 24(4) Global Change Biology 1405, 1405-16 (2018), https://www.ncbi.nlm.nih.gov/pubmed/29245177. Accessed 29 August 2022.*
122. *See Alice A. Horton et al., Microplastics in Freshwater and Terrestrial Environments: Evaluating the Current Understanding to Identify the Knowledge Gaps and Future Research Priorities, 586 Sci. of The Total Env't 127, 127-41 (2017), https://www.ncbi.nlm.nih.gov/pubmed/28169032. Accessed 29 August 2022.*
123. *See Luca Nizzetto, Sindre Langaas & Martyn Futter, Pollution: Do Microplastics Spill on to Farm Soils?, 537 Nature 488 (2016), https://www.nature.com/articles/537488b. Accessed 29 August 2022.*
124. *See Michael O. Gaylor, Ellen Harvey & Robert C. Hale, Polybrominated Diphenyl Ether (PBDE) Accumulation by Earthworms (Eisenia fetida) Exposed to Biosolids-, Polyurethane Foam Microparticle-, and Penta-BDE-Amended Soils, 47(23) Envtl. Sci. & Tech. 13831, 13831-839 (2013), https://pubs.acs.org/doi/abs/10.1021/es403750a. Accessed 29 August 2022.*
125. *See Yooeun Chae & Youn-Joo An, Current Research Trends on Plastic Pollution and Ecological Impacts on the Soil Ecosystem: A Review, 240 Envtl. Pollution 387, 387-95 (2018), https://doi.org/10.1016/j.envpol.2018.05.008. Accessed 29 August 2022.*
126. *See Ee-Ling Ng et al., An Overview of Microplastic and Nanoplastic Pollution in Agroecosystems, 627 Sci. of The Total Env't 1377, 1377-88 (2018), https://doi.org/10.1016/j.scitotenv.2018.01.341. Accessed 29 August 2022.*
127. *See Teresa Rocha-Santos & Armando C. Duarte, A Critical Overview of the Analytical Approaches to the Occurrence, the Fate and the Behavior of Microplastics in the Environment, 65 TrAC Trends in Analytical Chemistry 47, 47-53 (2015), https://doi.org/10.1016/j.trac.2014.10.011. Accessed 29 August 2022.*
128. *See Samantha E. Serrano et al., Phthalates and Diet: A Review of the Food Monitoring and Epidemiology Data, 13(1) Envtl. Health 43 (2014), https://doi.org/10.1186/1476-069X-13-43. Accessed 29 August 2022.*
129. *See Thomas McGrath, Andrew S. Ball & Bradley Clarke, Critical Review of Soil Contamination by Polybrominated Diphenyl Ethers (PBDEs) and Novel Brominated Flame Retardants (NBFRs); Concentrations, Sources and Congener Profiles, 230 Envtl. Pollution 741, 741-57 (2017), https://www.ncbi.nlm.nih.gov/pubmed/28732337. Accessed 29 August 2022.*
130. *See Jian Lu et al., Analysis of Bisphenol A, Nonylphenol, and Natural Estrogens in Vegetables and Fruits Using Gas Chromatography–Tandem Mass Spectrometry, 61(1) J. of Agric. & Food Chemistry 84, 84-89 (2013), https://pubs.acs.org/doi/abs/10.1021/jf304971k. Accessed 29 August 2022.*
131. *See Principle for Responsible Investing, 'The plastics landscape: regulations, policies and influencers' (last visited on 06/05/2022) https://www.unpri.org/plastics/the-plastics-landscape-regulations-policies-and-influencers/4953.article. Accessed 29 August 2022.*
132. *See The Guardian, 'Plastic summit could be most important green deal since Paris accords, says UN' (last vsited on 06/05/2022) https://www.theguardian.com/environment/2022/feb/25/plastic-summit-could-be-most-important-green-deal-since-paris-accords-says-un. Accessed 29 August 2022.*
133. *See The Guardian, 'World leaders agree to draw up 'historic' treaty on plastic waste' (last visited on 06/05/2022) https://www.theguardian.com/environment/2022/mar/02/world-leaders-agree-draw-up-historic-treaty-plastic-waste. Accessed 29 August 2022.*
134. *See Edson Luiz dos Santos, 'Payments, The Evolution of Means of Payment' (2017) https://play.google.com/books/reader?id=XtIPEAAAQBAJ&pg=GBS.PT1&hl=en_GB. Accessed 29 August 2022.*
135. *See Edson Luiz dos Santos, 'Payments, The Evolution of Means of Payment - The Brave New World of Cards'' (2017)*
136. *Cardknox "Payment Methods: A Brief History and a Look to the Future" https://www.cardknox.com/white-papers/payment-methods-history-and-future/#:~:text=A%20Brief%20History%20of%20Money,what%20is%20now%20western%20Turkey. Accessed 29 August 2022.*
137. *'The Future of Payments - Part III. Digital Currencies: the Ultimate Hard Power Tool' - Deutsche Bank Research, Corporate Bank Research (2020) https://www.dbresearch.com/PROD/RPS_EN-PROD/PROD0000000000504589/The_Future_of_Payments_-_Part_III__Digital_Currenc.pdf?undefined&realload=wk5kS3JdSjaSxKzUvBMxEOR/6qOVfhfb4IZ9lA6/zPCm8rZhJWw6iqMQQtX30Nkz. Accessed 29 August 2022.*
138. *Deutsche Bank dbDIG "The Future of Payments - Part II Moving to Digital Wallets ad the Extinction of Plastic Cards" (2020) https://www.dbresearch.com/PROD/RPS_EN-PROD/PROD0000000000504508/The_Future_of_Payments_-_Part_II__Moving_to_Digita.pdf?undefined&realload=~ehJzcE9HrnVeSdP1NnTyc0Q2vFeaGGZ1AFEWQqfN9ZnLMF~Xx/Ufq/IzCXAfntD. Accessed 29 August 2022.*
139. *https://p2pfoundation.ning.com/forum/topics/bitcoin-open-source. Accessed 29 August 2022.*
140. *River Financial "What Is the Byzantine Generals Problem?"https://river.com/learn/what-is-the-byzantine-generals-problem/#:~:text=The%20Byzantine%20Generals%20Problem%20is,agree%20on%20a%20certain%20truth%3F. Accessed 29 August 2022.*
141. *Deutsche Bank dbDIG "The Future of Payments - Part III - Digital Currencies: the Ultimate Hard Power Tool" (2020). https://www.dbresearch.com/PROD/RPS_EN-PROD/PROD0000000000504589/The_Future_of_Payments_-_Part_III__Digital_Currenc.pdf?undefined&realload=LV4D839dvcAAq1GwOya2ORoepZIfrnI4TiB~xubO~DGoU9Eu3rHJ/27NApouG6c1. Accessed 29 August 2022.*
142. *Pew research "*Public Trust in Government: 1958-2022*" https://www.pewresearch.org/politics/2022/06/06/public-trust-in-government-1958-2022/ 1. Accessed 29 August 2022.*
143. *DiEM25 "Why Bitcoin is not a socialist's ally: Reply to Ben Arc" https://diem25.org/why-bitcoin-not-socialists-ally-reply-ben-arc/. Accessed 29 August 2022.*
144. *Sketchplanations "The tragedy of the Commons" https://sketchplanations.com/the-tragedy-of-the-commons. Accessed 29 August 2022.*

145. ISO "ISO/IEC 7810:2019 Identification cards - Physical characteristics" https://www.iso.org/standard/70483.html. Accessed 29 August 2022.
146. Madehow "Credit card" http://www.madehow.com/Volume-4/Credit-Card.html. Accessed 29 August 2022.
147. The Guardian "Just 7% of UK shop payments predicted to be in cash by 2024 – report" https://www.theguardian.com/money/2021/jun/01/just-7-of-uk-shop-payments-predicted-to-be-in-cash-by-2024-report. Accessed 29 august 2022.
148. Statista "Number of credit, debit and prepaid cards in circulation worldwide from 2017 to 2021, with forecasts for 2023, 2025, and 2026" https://www.statista.com/statistics/1080756/number-payment-cards-in-circulation-worldwide/. Accessed 29 August 2022.
149. Finder "UK credit card statistics" https://www.finder.com/uk/credit-card-statistics. Accessed 29 August 2022.
150. Finextra "Former MBNA director Michael Donald launches virtual card kit with moving images" https://www.finextra.com/pressarticle/86742/former-mbna-director-michael-donald-launches-virtual-card-kit-with-moving-images. Accessed 29 August 2022.
151. Globe News Wire "Study: More than half of the world's population will use." https://www.globenewswire.com/en/news-release/2021/07/08/2259605/0/en/Study-More-than-half-of-the-world-s-population-will-use-mobile-wallets-by-2025.html. Accessed 29 August 2022.
152. Pay Space Magazine "Top 10 payment cards made out of unusual materials" https://payspacemagazine.com/banks/top-10-payment-cards-made-out-of-unusual-materials/. Accessed 29 August 2022.
153. 'Sustainable debit cards - Phase 1: Life cycle scan of alternatives' TNO Report for Betaalvereniging Nederland - Dr. T.N. Ligthart, Drs. A.K. van Harmelen, Drs. P.R. Willemsen (2019)
154. Statista "Global plastics production volume forecast worldwide". https://www.statista.com/statistics/664906/plastics-production-volume-forecast-worldwide/. Accessed 29 August 2022.
155. PWC 'PwC: The rise of the eco-friendly consumer', June 2021 Global Consumer Insights Pulse Survey. https://www.strategy-business.com/article/The-rise-of-the-eco-friendly-consumer. Accessed 29 August 2022.