# ENVIRONMENTAL IMPACT OF POLYMER PRODUCTION

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## What are the effects of polymer production on the environment ?

## Introduction

Polymers are materials which consist of small units called monomers and are bound together by the process called polymerisation. Naturally occuring polymers like wood or cotton have been man's tools for centuries. Synthetic polymers have been studied and used since the early 1800s and have constituted a prolific field of research ever since.

Polymer lifecycle can be divided into 3 parts, namely production, usage and disposal. Disposal may include reuse, recycling or being dumped in the landfills. Although polymers have been a boon in terms of mechanical strength to weight ratio, and display harsh environmental tolerance like humidity or rusting, they still present many disadvantages. People are well aware of the damages polymers cause in their usage and disposal state. There has been numerous studies, followed by campaigns to avoid or ban single use plastics and the microplastic accumulation along the food chain.

However, waste and pollution do not only occur at the very end of the lifecycle of polymers. This poster discusses the lesser known facts about the polymer production phase and some of the myths revolving around it.

Production > Usage > Disposal

## Comparison to other materials

**5-6%** of worldwide energy consumption comes from the steel industry.

50% of this energy derives from coal, 5% from natural gas.

Mass of $CO_2$ generated during the entire lifecycle of a bottle made in plastic: **129 g** / made in glass: **345 g**

**1 ton of glass** = **700 kg** of sand, **200 kg** of limestone, **300 kg** of other mineral raw materials

All are abundantly found in the nature, unlike petroleum (used for polymer production).

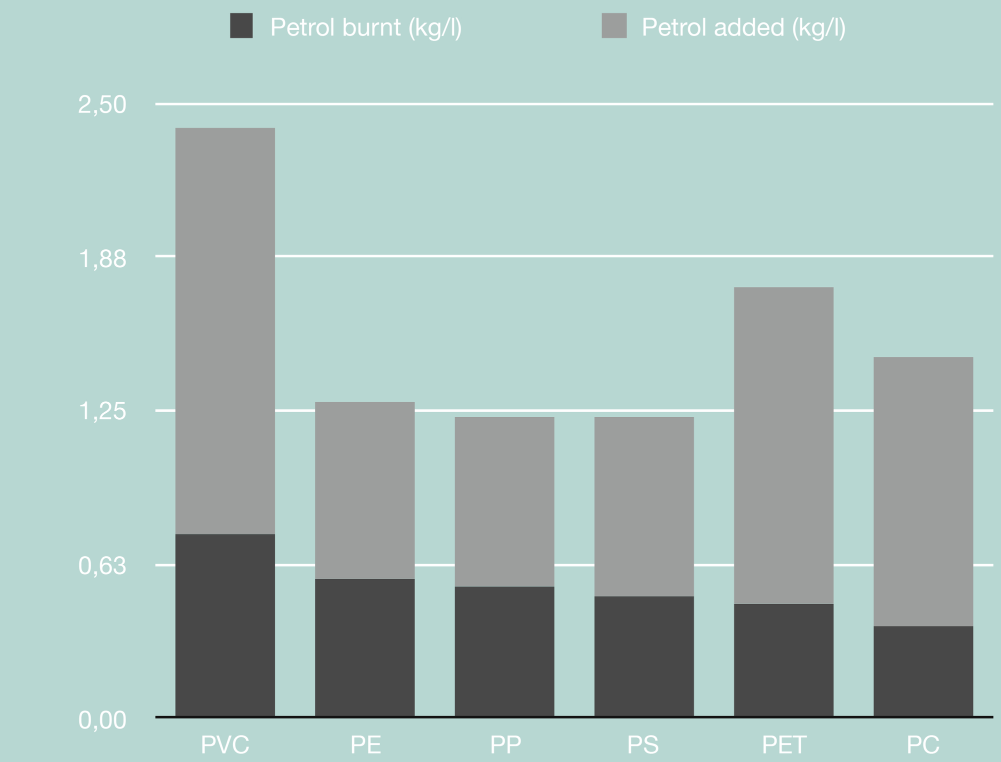
## 1. Oil-based and gas-based polymers : natural resources depletion

Some polymers are derived from petroleum feedstocks. Synthetic polymers like polyethylene (PE), polypropylene (PP), nylon, polyester (PS), polytetrafluoroethylene (PTFE), and epoxy (commonly known as plastic) are derived from petroleum hydrocarbons.

In the US, plastic manufacture (as a feedstock and energy source) is estimated to consume approximately 4.6% of total oil consumption and in Europe, it is estimated that between 4–6% of oil and gas is used for producing plastics. By contrast, 87% is used for transport, electricity and heating (meaning it is simply burnt and lost). However, only 4% of the worlds fossil resources are used in plastic production which is a minor contribution towards the oil depletion compared to the other industrial usage.

Bio-based polyols in polyurethanes synthesis represent the major part of PU, generally between 60 to 70% in weight of PU. Most of bio-based polyols for polyurethanes are synthesized from vegetable oils. The vegetable oils, with a worldwide production of around 150 million t/year, are used mainly in human food applications (75%), but the technical uses are increasing (13% is used in oleochemical industry).

Petrol consumption in plastic making for different plastics:




In order to obtain those figures, it was considered that one litre of petrol (0.76 kg) derives from approximately 0.9 kg of crude oil. Knowing how much oil is needed to produce a specific amount of plastic, it leads to a plastic to petrol ratio in kg/l. Two uses of petrol in plastic production are distinguished: as a fuel and as a raw material.

## 2. Polymerization process : energy consumption

The formation of repeating units for thermoplastics begins with the formation of their monomers from small carbon-based molecules derived from raw materials as petrol. Those monomers are then joined together through the process of polymerization.

In order to polymerize, the molecules need to be heated at a temperature higher than their glass transition temperature before cooling. The higher the temperature, the faster the polymerization process will occur, such as most reactions. However, a temperature too high would also degrade the newly formed polymer chain. Therefore, the heat must be carefully controlled during the entire process.

**22 kWh/kg** are used during the entire polymerization process

→ **0.38 kWh/kg** of direct electrical consumption, the rest is due to feedstock and steam cracking energies

**$0.4 \times 10^{14}$ kWh** net heat generation from the use of crude oil in plastic making from 1939 to 2000

It corresponds to 1.3% of the missing heat and contributes to 0.5% of the global warming. Its contribution is about the same magnitude than the gas flaring, less than the impact of nuclear power, and more than coal fires.

However, polymerization is an exothermic reaction : it is therefore theoretically possible to regulate the heat inside of the reactor to adapt its consumption to the lowest possible, thus using the heat produced by the process to make it keep going. Nonetheless, the glass transition temperature of the polymer will increase as it forms larger chains: it means that the overall temperature of the reactor should increase in order to remain above the glass transition temperature. It then becomes difficult to conjugate all those variables and find the optimum temperature which would be high enough to allow polymerization but consume the least energy by reusing the heat created by the reaction, all the while making sure the temperature is not high enough to degrade the chain.

## 3. Volatile organic compounds and other by-products

Extremely large quantities of chlorine-rich hazardous wastes are generated in the synthesis of ethylene dichloride (EDC) and vinyl chloride monomer (VCM)—the feedstocks for PVC.

These chemical mixtures include such extremely hazardous and long-lived pollutants as the chlorinated dioxins (polychlorinated dibenzo-p-dioxins), chlorinated furans (polychlorinated dibenzofurans), polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB), and octachlorostyrene (OCS). In addition, large portions of these mixtures consist of chemicals that have not yet been identified or tested.

Dioxins (2,3,7,8- tetrachlorodibenzo-p-dioxins) are never manufactured intentionally but are formed accidentally whenever chlorine gas is used or chlorine-based organic chemicals are burned or processed under reactive conditions. When its entire lifecycle is considered, PVC appears to be associated with more dioxin formation than any other single product. Dioxin is the most potent synthetic carcinogen ever tested in laboratory animals and is a known human carcinogen.

Phthalates are not chemically bonded to the plastic but are mixed with the polymer during formulation. They therefore leach out of the plastic over time into air, water, or other substances which pose considerable health and environmental hazards.

Most of the mercury used for polymer production is recycled, but significant quantities are routinely released into the environment via air, water, products, and waste sludges.

Epichlorohydrin, an organochlorine used in the production of wet strength resin, which is used to increase the tensile strength of paper products is also one of the hazardous air pollutants (HAP), mainly Epichlorohydrin is considered a probable human carcinogen.

Leaning towards clean technology, which deals with environmentally related investments in the process instead of the end products and desire to reduce pollutant emissions (VOCs) at the source.

## Authors & sources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