

Plastic, Paper or Cotton: Which Shopping Bag is Best?

BY RENEE CHO | APRIL 30, 2020



Photo: [betuli](#)

On March 1, New York State instituted its plastic bag ban, joining seven other states in an attempt to lessen litter, garbage in landfills, ocean pollution, and harm to marine life. March 1 was also the day that New York acknowledged its first coronavirus case. And despite the fact that California was the first state to ban plastic bags in 2014, San Francisco has reversed its plastic bag ban because of the coronavirus, outlawing the use of reusable shopping bags, which are capable of spreading viral and bacterial diseases. New Hampshire, Massachusetts, Oregon and Maine have also banned reusable bags or delayed their plastic bag bans for now as have a number of cities.

Given the concerns pulling us in different directions—our health, the environment, climate change—what's an environmentally responsible, health-conscious shopper to do? Let's compare the main bag choices—plastic, paper and cotton—to try to answer that question.

Life Cycle Analysis

To understand the full spectrum of impacts and benefits of a particular bag, we need to analyze its life cycle. A life cycle analysis (LCA) looks at how much energy is used and how many environmental impacts a product is responsible for at every stage of its life, from cradle to grave. This includes extracting the raw materials, refining them, manufacturing the product, packaging it for shipment, transporting and distributing it, its use and possible reuse, recycling and final disposal.

In any LCA, the total environmental impact also depends on how efficient each process is, and how many protective environmental measures are implemented at every stage. Energy use is also subject to variables such as the source of raw materials, the location of manufacturing and processing, how long a product is used and the final disposal method.

Life cycle studies done in Europe and North America have determined that, overall, plastic bags are better for the environment than paper or reusable bags unless the latter are used many times. Most, however, did not consider the problem of litter, which we know is a major drawback of plastic bags.

Plastic bags

Plastic bags were invented in 1967, but only became widely used in stores in the 1970s. The most commonly found thin plastic shopping bags given out at cash registers are usually made of high-density polyethylene (HDPE), but some are made of low-density polyethylene plastic (LDPE).



Photo: [Walmart](#)

The energy embodied in plastic bags comes initially from the mining of the raw materials needed to make them—natural gas and petroleum—whose extraction requires a lot of energy. The raw materials must then be refined, which requires yet more energy. Once at a processing facility, the raw materials are treated and undergo polymerization to create the building blocks of plastic. These tiny granules of polyethylene resin can be mixed with recycled polyethylene chips. They are then transported by truck, train or ship to facilities where, under high heat, an extruder shapes the plastic into a thin film. The film is flattened, then cut into pieces. Next, it is sent to manufacturers to be made into bags. The plastic bags are then packaged and transported around the world to vendors. While polyethylene can be reprocessed and used to make new plastic bags, most plastic bags are only used once or twice before they end up being incinerated or discarded in landfills. The *Wall Street Journal* estimated that Americans use and dispose of 100 billion plastic bags each year; and the EPA found that less than five percent are recycled.

A [2014 study](#) done for the Progressive Bag Alliance, which represents the U.S. plastic bag manufacturing and recycling industry, compared grocery bags made from polyethylene (HDPE), compostable plastic, and paper with 30 percent recycled fibers. It found that the HDPE bags ultimately used less fuel and water, and produced less greenhouse gas gases, acid rain emissions, and solid waste than the other two. The study, which did not consider litter, was peer-reviewed by Michael Overcash, then a professor of chemical engineering at North Carolina State University. Because the carrying capacity of a plastic and a paper bag are not the same, the study used the carrying capacity of 1,000 paper bags as its baseline and compared their impacts to the impacts of 1,500 plastic bags. The plastic bags used 14.9kg of fossil fuels for manufacturing compared to 23.2kg for paper bags. Plastic bags produced 7kg of municipal solid waste compared to 33.9kg for paper, and greenhouse gas emissions were equivalent to 0.04 tons of CO₂ compared to paper's 0.08 tons. Plastic bags used 58 gallons of fresh water, while paper used 1,004 gallons. Energy use totaled 763 megajoules for plastic, and 2,622 megajoules for paper.

Sulfur dioxide, a type of sulfur oxide, and nitrogen oxide emitted from coal-fired power plants that produce the energy for processing bags contribute to acid rain. The plastic bag produced 50.5 grams of sulfur oxides compared to 579 grams for the paper bag; and 45.4 grams of nitrogen oxides, compared to 264 grams for paper.

A [2011 U.K. study](#) compared bags made of HDPE, LDPE, non-woven polypropylene, a biopolymer made from a starch polyester, paper and cotton. It assessed the impacts in nine categories: global warming potential, depletion of resources such as fossil fuels,

acidification, eutrophication, human toxicity, fresh water toxicity, marine toxicity, terrestrial toxicity and smog creation. It found that HDPE bags had the lowest environmental impacts of the lightweight bags in eight of the nine categories because it was the lightest bag of the group.



Photo: [Zainub Razvi](#)

But because they are light and easily blown around, plastic bags are difficult to dispose of properly. They litter streets and trees, and wash into the ocean where they entangle and are consumed by marine life. They are rarely recyclable and can take 20 to 1,000 years to break up into pieces. Over time, sun and heat do break plastics into smaller and smaller pieces, forming microplastics under five millimeters long. These have been found everywhere—in the guts of marine animals and in waterways and on beaches around the world. So while these life cycle studies have not considered litter as an

impact, the world recognizes that the omnipresence and persistence of plastic waste is an enormous environmental problem.

In terms of bag choice, Steve Cohen, director of the Research Program on Sustainability Policy and Management at the Earth Institute, said that it's very hard to predict whether plastic, paper or cloth bags are the best in terms of net energy or carbon, because they all use carbon. "But once a product that's made of fossil fuels, like a plastic bag, hits the waste stream, it's there forever," he said. "That's the biggest problem with the plastic."

Which is not to say that plastic has no value. In this time of coronavirus, most of the personal protective equipment is made of plastic. "That's what you should be using it for," said Cohen, "But the idea that you need it to carry around your grapefruits is kind of silly. It's unnecessary."

Non-woven polypropylene cloth-like plastic totes that are often given away free as publicity are stronger and more durable than HDPE and LDPE plastic bags, and thus can be used multiple times.



Non-woven polypropylene bag. Photo: [Princeton Public Library](#)

They are made from polypropylene polymers derived from fossil fuels, and can include recycled material. The polymers are spun into threads then pressed together between heated rollers to produce a fabric that feels similar to canvas. According to a [California State University, Chico study](#), if comparing one-time use, the non-woven polypropylene bags use considerably more non-renewable energy and fresh water than single-use plastic bags. Moreover, they are not biodegradable and need to be washed to avoid contamination—COVID-19 has been found to survive on polypropylene for three days.

Paper bags

Paper bags are made from a renewable resource and are biodegradable. In the U.S., over 10 billion paper bags are consumed each year, requiring the felling of 14 million trees.



Photo: [Beth](#)

Once the trees are cut down, the logs are moved to a mill where they can wait up to three years until they dry out. Once ready, bark is stripped off and the wood is chipped into one-inch cubes that are subjected to high heat and pressure. They are then mixed with limestone and sulfurous acid until the combination becomes pulp. The pulp is washed with fresh water and bleach then pressed into paper, which is cut, printed, packaged and shipped. As a result of the heavy use of toxic chemicals in the process, paper is responsible for 70 percent* more air pollution and 50 times more water pollution than plastic bag production according to a [Washington Post analysis](#), resulting in more toxicity to humans and the environment than HDPE bags. And while 66 percent of paper and paperboard are recycled, the recycling process requires additional chemicals to remove the ink and return the paper to pulp, which can add to paper's environmental impact.

A [2005 Scottish study](#) also found that paper bags scored more poorly than plastic on water consumption, atmospheric acidification and the eutrophication of water bodies, which can lead to growth of algae and depletion of oxygen.

A [Danish study](#) comparing LDPE, polypropylene, bleached and unbleached paper, and cotton bags, and a few others, found that LDPE bags had the lowest environmental impact. Unbleached paper bags were found to equal the LDPE bags in terms of global warming potential. But the environmental impacts of bleached paper were considerably higher than those of unbleached paper—a bleached paper bag would need to be reused 43 times to equal the LDPE's environmental impact.

A portion of paper bags' environmental impact results from their being six to 10 times heavier than plastic bags, so transporting and distributing them requires more fuel and costs more. One estimate maintained that it would take seven trucks to transport the same number of paper bags as can be transported by a single truck full of plastic bags. Their bulk also takes up more space in inventories and landfills.

The extent of impacts from paper bags, however, depends on whether the forest is sustainably managed and also on the environmental measures used in the paper processing plant.

Cotton totes

Cotton bags are made from a renewable resource and are biodegradable. They are also strong and durable so they can be reused multiple times.

Cotton first needs to be harvested, then cotton bolls go through the ginning process, which separates the cotton from stems and leaves. Only 33 percent of the harvested cotton is usable. The cotton is then baled and shipped to cotton mills to be fluffed up, cleaned, flattened and spun. The cotton threads are woven into fabric, which then undergoes a chemical washing process and bleaching, after which it can also be dyed and printed. Spinning, weaving and other manufacturing processes are energy intensive. Washing, bleaching, dyeing, printing and other processes use large amounts of water and electricity.



Photo: [Gina Koo](#)

The Danish and U.K. studies and several others found that cotton totes have the worst environmental impacts of all bags. Cotton requires land, huge quantities of water, and chemical fertilizers and pesticides to grow. The use and production of fertilizer contribute significantly to eutrophication. Harvesting, processing, and transporting

cotton to market all require large amounts of energy; and since cotton totes are heavy and bulky, they cost more to ship. In addition, they are difficult to recycle since textile recycling in the U.S. is limited—only 15.2 percent of all textiles were recycled in 2017. As a result, a cotton bag needs to be used 7,100 times to equal the environmental profile of a plastic bag.

Bags made from organic cotton, grown without pesticides, fare even worse environmentally. Because organic cotton yields are 30 percent less than conventional cotton, they need 30 percent more water and land to produce the same amount as conventional cotton. Organic cotton bags need to be used 20,000 times to equal the environmental impact of plastic bags.

Today, another critical factor to consider is that cotton and other reusable shopping bags can carry bacteria and transfer it from home to grocery carts and checkouts and back again. One [study of reusable bags](#) discovered that they were rarely washed and as a result, bacteria were found in almost all the bags studied, with 12 percent containing *E. coli*. While most reusable bags are made of polypropylene, upon which COVID-19 has been shown to survive three days, so far there are no scientific findings about how long the coronavirus can survive on clothing or textiles. However, in a [2005 study](#) of the SARS virus, another coronavirus, it survived on cotton for five minutes to one hour depending on the amount of exposure.

To be safe, wash reusable bags in warm or hot water after shopping, which can reduce the bacteria by 99.9 percent and kill COVID-19. Only use the bags for groceries and ideally, put meats into a separate bag since meat juices left in bags can enable bacteria to grow quickly. Don't leave reusable bags in the car because when it gets hot, bags become an ideal place for bacteria to grow.

The final outcome

Generally speaking, bags that are intended to last longer are made of heavier materials, so they use more resources in production and therefore have greater environmental impacts. To equal the relatively low global warming impact of plastic bags, paper and cotton bags need to be used many times; however, it's unlikely that either could survive long enough to be reused enough times to equal the plastic bag's lower impact.

Ultimately, the single use of any bag is the worst possible choice. The key to reducing your environmental impact is to use whatever bags you have around the house as many times and in as many ways as possible. It's understandable if, during this time of COVID-19, you've reverted to plastic bags to protect yourself and are probably discarding them after a one-time use. But when the risk of COVID-19 abates, remember to try to use whatever bag you choose as many times as possible. HDPE or LDPE bags

can be used to store food, line wastebaskets, pick up dog poop, pack lunches, pad packages, stash wet umbrellas and in many more ways.

Cohen believes that the important issue isn't so much the specific environmental impact of the packaging you use, however, but what it is doing to your behavior pattern.

"What's key is to get people conscious of packaging and to start thinking about closing the loop from production to consumption," he said. "We're trying to build a set of consumer behaviors that are environmentally conscious, so I wouldn't just look narrowly at the specific environmental impact of the form of packaging. I would be thinking more about what it is teaching people about being conscious of how their goods are moving around and being packed and disposed of."

**Editor's note, 10/19/22: A previous version of this story incorrectly stated that paper bags create 70 times more air pollution. We have corrected the sentence and we regret the error.*