THE NEW COAL

PLASTICS & CLIMATE CHANGE

Beyond Plastics | October 2021

BEYOND PLASTICS
BENNINGTON COLLEGE

ACKNOWLEDGEMENTS

This analysis builds from others already published. The most prominent of these, *Plastic & Climate: The Hidden Costs of a Plastic Planet (2019)*, provides an analysis of greenhouse gas emissions by the petrochemical industry worldwide and identifies sources that were previously uncounted.

This report further draws upon the Environmental Integrity Project (EIP)'s on-going reporting of the petrochemical buildout in the United States. EIP's Emissions Increase Database has provided fundamental grounding for this report.

Material Research president, Jim Vallette is the lead researcher and author of this report. Connie Murtagh, Verónica Odriozola, Jill Weber, and Bart Libaut provided additional research assistance.
http://www.materialresearch.net

Megan Wolff, PhD, Judith Enck, Caroline Pryor, Andre Carothers, Jennifer Congdon, Eve Fox, Alexis Goldsmith, and Lane Epps contributed valuable editing.

We are grateful especially to Alexandra Shaykevich of the EIP for her review of our spreadsheet of plastics-related facilities, to Angela Soliz Design for her skill in designing the report, and to Judith Enck, whose vision beyond plastics has inspired us and prompted this analysis.

Cover photo courtesy of Alejandro Dávila Fragoso/ Earthjustice (Sharon Lavigne, community leader in Louisiana).

Design: Angela Soliz | www.angelasoliz.co

One College Drive
Bennington, Vermont 05201
www.BeyondPlastics.org
ISBN: 978-0-578-30445-8

ISBN 978-0-578-30445-8
90000>
9 780578 304458

TABLE OF
CONTENTS

PLASTICS IS THE FOSSIL FUEL INDUSTRY'S PLAN B. BUT THERE IS NO PLAN B FOR THE REST OF US.

FOREWORD BY JUDITH ENCK

Plastic production is the last gasp of the fossil fuel industry.

Made from a combination of chemicals and fossil fuels, plastic produces greenhouse gas emissions at every stage of its life cycle. To provide context, if plastic were a country, it would be the world's fifth largest greenhouse gas emitter, beating out all but China, the U.S., India and Russia[1].

Yet few policy makers and even fewer businesses are addressing plastic's impact on our rapidly warming climate, and working to limit its ballooning greenhouse gas emissions. Unlike the plastic trash choking our waterways and littering our communities, the plastic industry's devastating impact on our climate is taking place under the radar, with little public scrutiny and even less government accountability.

This report documents the plastic sector's staggering contribution to greenhouse gas emissions in the United States which is now poised to surpass those of coal-fired power plants. **Plastic is the new coal.**

According to Bloomberg Philanthropies and Beyond Coal, 65% of coal plants nationwide have been retired – a remarkable drive toward cleaner energy that has taken decades of hard work by many. But the hard-won reductions in greenhouse gas emissions from coal plants are being quickly cancelled out by a new universe of climate-warming emissions from plastics.

Incredibly, this radical shift in the source of our deepening climate crisis is taking place without notice. Plastic is rarely mentioned when climate change policies are debated at a state, federal or international level. If we hope to remain within the 1.5 degree C global temperature rise scientists agree is necessary to avoid the worst ravages of climate change, that has to change, and quickly.

According to the International Energy Agency (IEA), petrochemicals will account for more than a third of the growth in world oil demand by 2030, and nearly half of the growth by 2050. The IEA reports "demand for plastics – the key driver for petrochemicals from an energy perspective – has outpaced all other bulk materials (such as steel, aluminum, or cement) nearly doubling since 2000." Further, "After decades of stagnation and decline, the United States has re-emerged as a low-cost location for chemical production, thanks to the shale gas revolution, and is now home to around 40% of the global ethane-based petrochemical production capacity."

However, petrochemical production is not "low-cost" when you consider its greenhouse gas emissions, as well as the intense health and environmental damage caused by petrochemical facilities in places like "Cancer Alley" in Louisiana and parts of Texas and Appalachia. The costs of petrochemical production rise even more when you consider the mounting costs of climate change-fueled disasters in these and other communities across the country.

Plastic's production and disposal are both massive environmental justice issues that are rarely mentioned when climate change policy is debated in Washington or when leaders gather at international forums such as the United Nations Climate Change Conference (COP26) in Glasgow, Scotland. Plastic production facilities are almost always

Firefighter battling a wildfire. Photo by Fabian Jones via Unsplash.

located in low-income communities and communities of color, as are the landfills and incinerators that serve as the "final resting place" for many plastic products. All of these facilities are highly polluting and take a toll on the health of nearby residents, as well as diminishing property values in their communities.

Nor do the environmental justice impacts of plastics end at our borders. The United States shipped roughly 1.4 billion pounds of plastic trash overseas in 2020[2], sending the majority to developing countries[3] that lack the local infrastructure and markets to deal with this influx of plastic. As a result, our exported plastic trash is often burned in the open, damaging the health of local communities or discarded in waterways or in open pits thousands of miles away[4]. Not only does America's "waste colonialism" come with a heavy carbon footprint as a result of shipping trash halfway around the world, it's also a global extension of the way we treat low-income communities as a dumping ground for pollution.

The burning of fossil fuels has already created what UN Secretary General António Guterres referred to as a "code red for humanity" following the release of the Intergovernmental Panel on Climate Change (IPCC) report in August of 2021[5].

This summer featured our frightening "new normal" -- a heatwave so extreme that it scorched endangered salmon and killed more than a billion marine animals in the Pacific Northwest[6], a host of mega-wildfires traversing Western mountain ranges that gutted communities and blanketed the nation in smoke, powerful hurricanes battering the Gulf Coast, deepening historic droughts, massive flooding in the Northeast, and more. Yet if we do not significantly reduce plastic production, the summer of 2021 may well be the least disaster-filled summer of the rest of our lives.

As countries finally begin to eliminate the burning of fossil fuels for power and transportation, the demand for fossil fuels is falling. In desperation, the fossil fuel industry is looking to plastics as a replacement market, as this report details.

Plastics is the fossil fuel industry's Plan B. But there is no Plan B for the rest of us.

Judith Enck, President, Beyond Plastics at Bennington College, October 2021

RESEARCH KEY

Because greenhouse gases are colorless and odorless, it can be difficult to imagine what a ton (or many tons) of these emissions look like or do, especially on a comparative scale. To assist with this difficulty, this report uses a symbol representing the amount of carbon dioxide equivalent (CO2e) released by a typical 500-megawatt coal-fired power plant (2 million tons in 2020).

CO2e is the shorthand way of expressing "Carbon dioxide equivalent." The term was adopted by the U.S. government as a way of comparing the global warming potential of any given greenhouse gas to that of carbon dioxide.

Each shaded symbol represents 2 million tons of greenhouse gas emissions from current plastics industry activities. This is the same amount released by a typical 500-megawatt coal-fired power plant in 2020.

Each unshaded symbol represents 2 million tons of potential greenhouse gas emissions from planned industry expansion by the year 2025.

All weights in this report are measured in U.S. tons (also called 'short' tons), not metric tons.

SUMMARY OF FINDINGS

The New Coal: Plastics & Climate Change is a comprehensive account of the United States plastics industry's contributions to the climate crisis. Using the coal-fired power industry as a benchmark, the report examines ten stages in the creation, use, and disposal of plastics. Key findings include:

Plastics manufacturing is currently a significant source of greenhouse gas emissions in the United States. More than 130 plastics facilities and related power plants report their emissions to the U.S. Environmental Protection Agency (EPA), providing a baseline figure that at least 114 million tons of carbon dioxide-equivalent (CO2e) gas are released from them per year. This is roughly equivalent to 57 average sized (500-megawatt) coal-fired power plants.

The petrochemical industry's plastics infrastructure is expanding, and emissions are slated to increase dramatically. At least 42 plastics facilities have opened since 2019, are under construction, or are in the permitting process. If they become fully operational, these new plastics plants could release an additional 55 million tons of CO2e gases – the equivalent of another twenty-seven 500-megawatt coal-fired power plants – by the year 2025.

The health impacts of emissions released by the plastics industry are disproportionately felt by low-income communities and people of color. More than 90% of the climate pollution that the plastics industry reports to EPA occurs in 18 communities, mostly along the coastlines of Texas and Louisiana. People living within 3 miles of these petrochemical clusters earn 28% less than the average U.S. household and are 67% more likely to be people of color.

"Chemical recycling" shares more in common with incinerating than recycling waste. While the industry has long made promises about plastic's recyclability, in truth, less than 9% of plastic is recycled. In response to criticism, the industry has issued new versions of these old promises, offering to build infrastructure that it describes as "advanced recycling" or "chemical recycling." These facilities do not recycle, however. Most spend vast amounts of energy catalyzing chemical changes designed to turn plastics into more burnable fuel. The burning of plastics made in the U.S. already releases an estimated 15 million tons of greenhouse gasses. With this process, it will release far more.

The New Coal: Plastics & Climate Change identifies other significant sources of greenhouse gas releases, some relatively obscure. For example, each year, at least 27 million tons of CO2e gases escape from foamed plastic insulation into the atmosphere.

Much of the ongoing buildout is export-oriented. Exports of gases, resins, and other feedstocks for plastics manufacturing, and imports of overseas plastics and related chemicals, are causing at least 41 million tons of CO2e to be released per year.

Overall, this report finds that **the U.S. plastics industry is responsible for at least 232 million tons of CO2e gas emissions per year.** This amount is equivalent to the average emissions from 116 average-sized (500-megawatt) coal-fired power plants in 2020. As the plastics industry continues to build infrastructure for export and production, its CO2e contributions will increase. As power plants close and petrochemical infrastructure expands in the U.S., the plastics industry's contribution to climate change will exceed that of coal by the year 2030[7].

Reports generated by the plastics industry are incomplete, and consequently understate the quantities of gases, especially methane gas, it releases. Industry reports are incomplete and the gap in data between what they report and the gases actually released conceals acute short-term implications for the climate. Most significantly, neither fossil fuel producers nor pipeline operators account for leaks that transpire during the manufacture or transport of feedstock, though such leaks are a regular occurrence with regular, measurable outcomes.

By actual weight, the extraction of fracked gases in the U.S. for plastics production at home and abroad releases at least 1.5 million tons of leaked methane each year. Because methane lingers for a dozen years in the atmosphere[8], these leaks are additive. They accumulate over time.

In the standard EPA greenhouse gas accounting method, methane is considered to be 25 times more harmful than carbon dioxide, so 1.5 million tons of leaked methane has the impact of 37.5 million tons of CO2e gas releases -- about what is released by nineteen 500-MW coal-fired power plants.

This analysis is a floor, not a ceiling, of the climate impacts from methane leakage. Methane's greenhouse gas effect is more than three times worse during the 12 years that this gas remains in the atmosphere, when it has at least 84 times the climate impact of carbon dioxide. Using that factor, the impact of methane leakage from plastics demand increases dramatically, to 126 million metric tons of CO2e gases.

This report's conclusions are based on an examination of these ten high-impact stages of plastics production, use and disposal:

1. Fracking for plastics.
2. Transporting and processing fracked gases.
3. Ethane gas crackers.
4. Other plastics feedstock manufacturing.
5. Polymer and resin manufacturing.
6. Exports and Imports.
7. Foamed plastic insulation.
8. "Chemical Recycling."
9. Municipal Waste Incineration.
10. Plastics in water.

For further details, please see Appendix 1, the Plastics & Climate Change Spreadsheet, which provides a facility-by-facility accounting of emissions. Appendix 2 explains the Methodology behind this report's calculations. Appendix 3 is a Glossary of Terms. Appendices are available along with this report on the Beyond Plastics website https://www.beyondplastics.org/plastics-and-climate.

SECTION 1

FRACKING FOR PLASTICS

This stage of plastics production – fracking in the United States for gases – releases an estimated 36 million tons of CO2e gases per year. This amount is roughly equivalent to the releases of eighteen average sized (500-megawatt) coal-fired power plants in 2020. Expansion in the U.S. and demand from overseas plastics manufacturers for gas obtained by hydraulic fracturing has the potential to cause the release of an additional 6 million tons CO2e, equal to three additional power plants.

In the 1990s, geological engineers in the United States perfected methods that coax natural gas and petroleum out of bedrock formations. This achievement touched off the largest energy boom the country has ever seen. Oil and gas producers have become adroit at drawing hydrocarbons to the surface by injecting high-pressure streams of “fracking fluid” (primarily water, containing sand and small ceramic balls suspended with the aid of chemicals) and “fracturing” the natural pressure contained within the rock. Since the turn of this century, petrochemical companies have drilled more than 1 million new oil and gas wells using this technique, called hydraulic fracturing[9].

Fracking profoundly reduced the cost of oil and gas, and increased its environmental impacts. Numerous sources have documented serious contamination of surface and ground water due to the release of fracking chemicals, as well as a reduction in air quality and even the triggering of earthquakes.

Another byproduct is the boom in plastics. The shale reservoirs being fracked are unusually rich in ethane, methane, and other gases that are particularly useful for making petrochemical plastics. The superabundance of fracked gases has turned the U.S. into the global engine of plastics production.

This step is also where the plastics industry’s climate burden starts because from the moment it is brought to the surface, methane begins to escape into the atmosphere[10]. Methane – also called natural gas – is the main component of fracked gases. It is used for electricity, cooking, and petrochemical production. Methane also is a very potent greenhouse gas, especially during the dozen years it remains in the atmosphere. As noted earlier, in the short-term, methane has 84 times the climate impact of carbon dioxide.

A recent review by scientists at Cornell and Stanford Universities found that on average, 2.6% of the methane produced at each wellhead passes directly into the atmosphere. The plastics industry consumes more than 1.5 billion U.S. tons of fracked gases annually[11]. At a leakage rate of 2.6%, this demand causes an estimated 36 million tons of CO2e equivalent gases during fracking each year.

“METHANE ESCAPES INTO THE ATMOSPHERE FROM ALL PARTS OF THE EXTRACTION, PROCESSING, AND DISTRIBUTION SYSTEM, ALL THE WAY TO THE BURNER TIP.”

– Dr. Robert Howarth of Cornell University and Dr. Mark Jacobson of Stanford University

SECTION 2

TRANSPORTING + PROCESSING FRACKED GASES

Pipelines stretch from fracking fields in Oklahoma, Texas, and Appalachia to Mont Belvieu, Texas, and outward to plastics producers across the Gulf Coast, from Corpus Christi, Texas, to Baton Rouge, Louisiana.

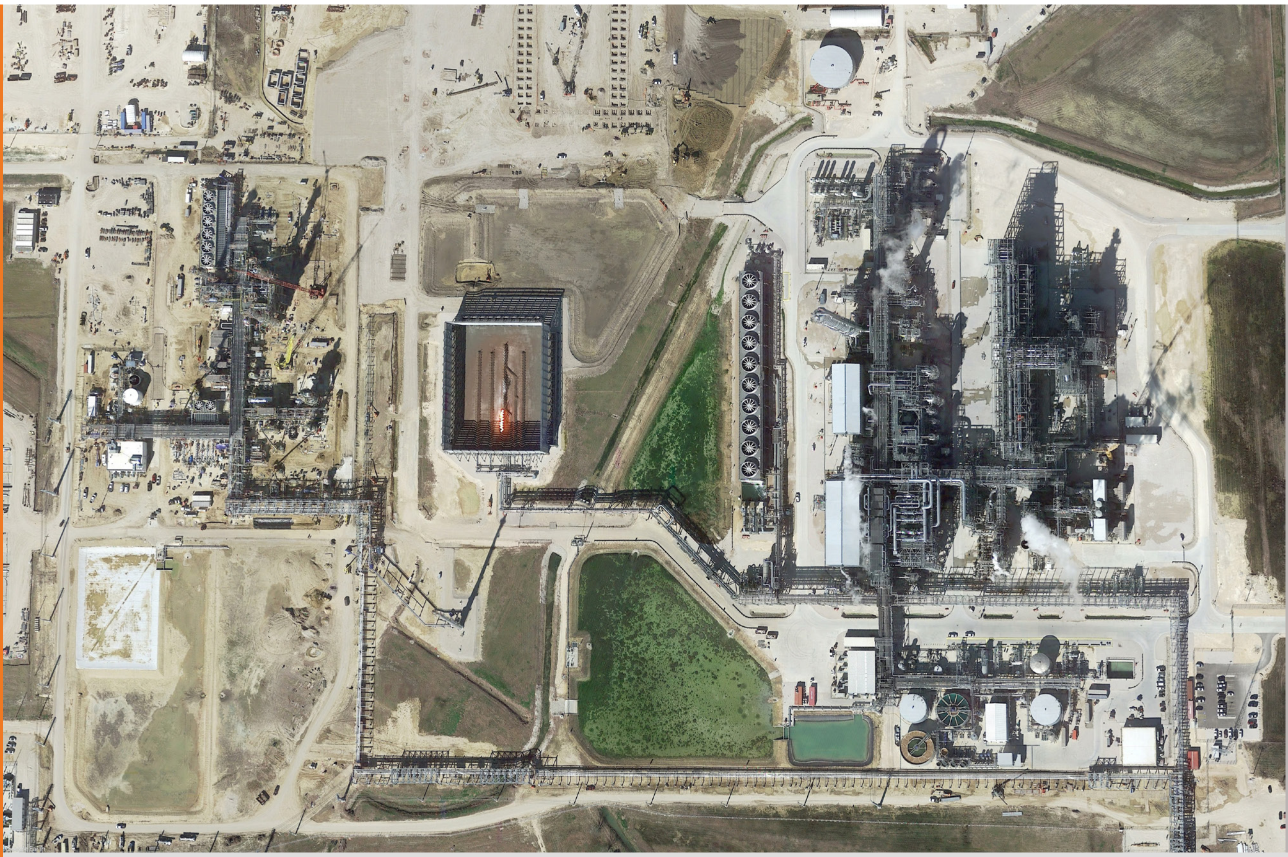
2021 → 2025

This stage of plastics production -- transporting and processing fracked gases -- releases at least 4.8 million tons of CO2e gases per year. This amount is roughly equivalent to the releases of two average sized (500-megawatt) coal-fired power plants in 2020. Expansion underway and planned has the potential to cause the release of an additional 4.7 million tons per year by the year 2025, equal to two additional power plants.

Once fracked gases have been extracted from the bedrock, pipelines deliver them to facilities that store and process them into individual components, such as methane, ethane, propane, and butane. These gases flow through more pipes to other facilities that store and process them.

As these fossil fuels are moved, more greenhouse gases escape into the environment, amplifying the rate and effects of climate change. Pipelines leak an estimated 0.8% of the methane that is delivered to plastics facilities for energy according to Dr. Howarth and Dr. Jacobson. Using this estimate, the plastics industry currently is responsible for another one million tons of methane leaks per year.

The epicenter of the U.S. plastics industry is just outside Houston,Texas, in a geological dome called Mont Belvieu. The 3,000-foot deep caverns of Mont Belvieu store most of the gases that are extracted by fracturing[12]. "Today, those caverns are increasingly filled with ethane



Fracked gas processing facility in Mt. Belvieu, Texas. Google Earth photo.

and other natural gas liquids that feed the plastics and chemical industries, making Mont Belvieu and its neighbor to the south, Baytown, the focal point of the Gulf Coast petrochemical boom," explains Jordan Blum of the Houston Chronicle[13].

Processing plants atop Mont Belvieu reflect this industry's rapid development. These include facilities called propane dehydrogenation units, which create plastics-ready propylene, and fractionators, which separate different gases by boiling them off from the rest of the stream. In 2010, gas processing plants at Mont Belvieu reported 1.2 million tons CO2e in emissions. Today, these plants emit more than 3 million tons CO2e each year, and planned expansions would be permitted to release another one to two million tons CO2e per year[14].

Pipelines stretch from fracking fields in the South Central U.S. and Appalachia, to Mont Belvieu, and onward to plastics producers across the Gulf Coast, from Corpus Christi, Texas, to Baton Rouge, Louisiana. A growing pipeline network reflects the fracking boom for plastics. In 2014, the Appalachia-Texas-Express pipeline started to deliver ethane from the Appalachian region to Midwest and Gulf Coast customers. The Mountain Valley Project pipeline, now under construction, could carry 2.4 billion cubic feet of natural gas per year through Pennsylvania, West Virginia, and Virginia. Developers of the pipeline intend to deliver gases to plastics plants and other industrial customers along the route[15]. This pipeline and related equipment, alone, will potentially release 2.3 million tons of CO2e per year by design, according to company applications reviewed by the Environmental Integrity Project[16].

Photo by DAVID R. TRIBBLE (top). Flaring of natural gas is a common practice that is both wasteful and polluting. iStock photo (bottom).

SECTION 3

ETHANE GAS CRACKERS

Facilities with ethane gas crackers released 70 million tons of CO2e gases in 2020. This amount was roughly equivalent to the releases of 35 average sized (500-megawatt) coal-fired power plants. Expansion has the potential to add another 42 million tons of greenhouse gases per year by the year 2025, equal to 21 coal-fired power plants. Emissions associated with extraction and delivery of feedstocks are accounted for in earlier stages.

The central players of plastics production are cracker plants, complexes where fracked gases are superheated until the molecules “crack” into new components, including ethylene. Abundant and inexpensive, ethylene enables the production of massive quantities of shopping bags, drinking straws, and other “disposable” consumer items[17].

The number of cracker plants in the United States has proliferated along with gas extraction.

In the year 2005, crackers were installed in 28 locations and had a combined capacity to produce 26.6 million tons of ethylene per-year.[18] Today, there are crackers in 35 locations with a combined 45 million tons-per-year capacity, a 69% growth over 15 years. At least 22 power plants are dedicated to these plastics factories. Combined, these crackers and power plants release at least 70 million tons of CO2e per year, a pace greater than that currently released by 35 average sized coal-fired power plants.

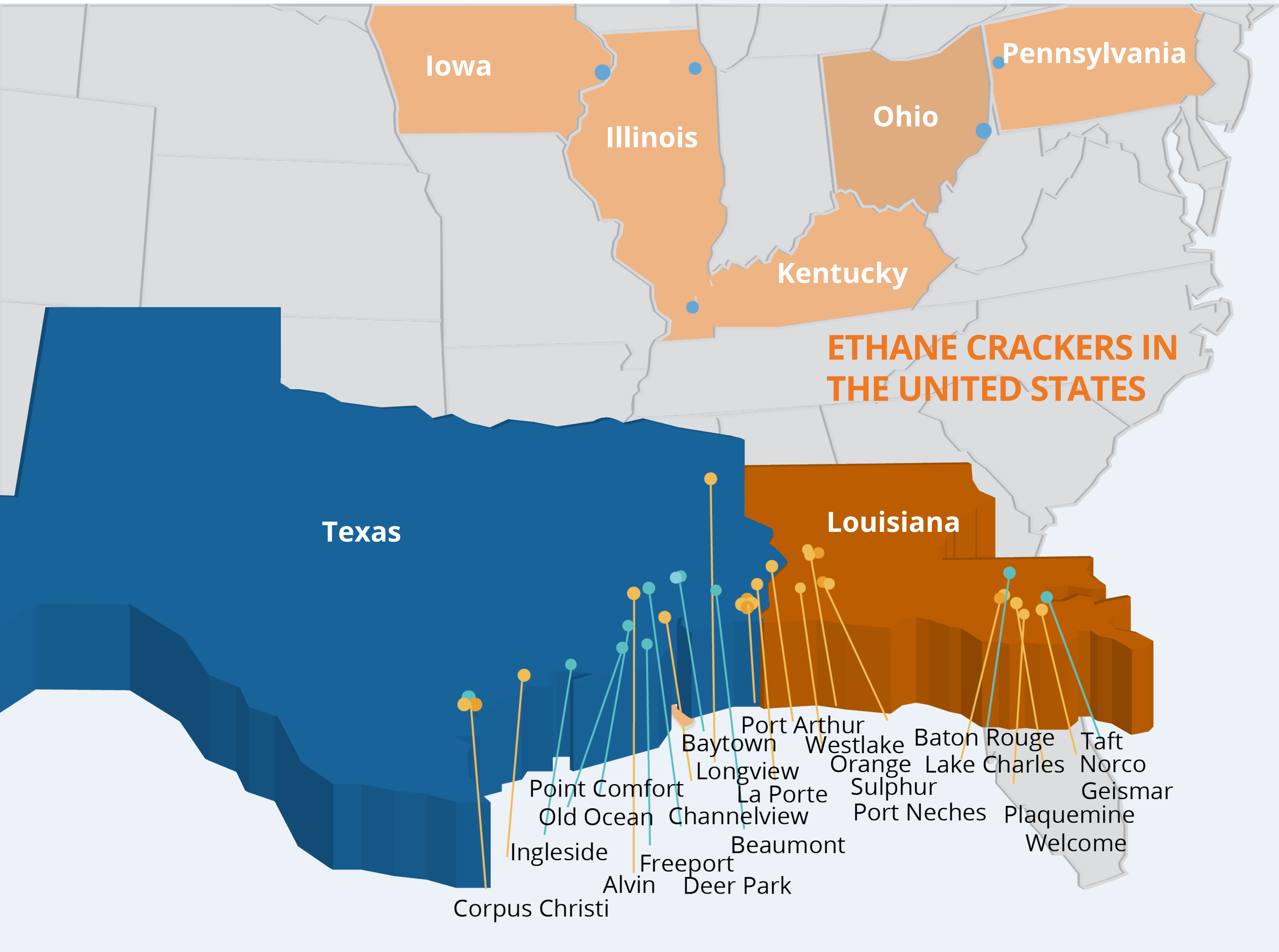
One of the largest plastics facilities in the world, Formosa Plastics in Point Comfort, Texas, has two natural gas power plants on-site. Even before it added a third cracker in 2019, Formosa produced enough energy to heat and power more than 422,000 homes, and used all of it to turn fracked gas into plastics[19].

The latest cracker to open was Baystar Polymers, near Mt. Belvieu, Texas. This is a joint venture between Total of France and Borealis of Austria. ExxonMobil and Sabic are finishing a new cracker in Corpus Christi, and Shell is close to opening the first big cracker of Appalachia, in Monaca, Beaver County, Pennsylvania. Their completion will bring the total number of ethylene cracker locations to 37, with a combined 49 million tons-per-year capacity, likely by the end of 2021, and result in millions more tons of greenhouse gas emissions.

Yet even more are on the way. At least three other giant cracking towers are under consideration. Formosa proposes to build the largest-ever standalone cracker (2.4 million tons ethylene per year) in St. James Parish, Louisiana, but that is now delayed due to community leaders’ successful request for a full environmental review by the U.S. Army Corps of Engineers. Thailand’s PTT Global Chemical plans to build a 1.5 million ton cracker in Mead Township, Ohio. ChevronPhillips Chemical is deciding whether to go ahead with a planned 2 million-ton cracker in Orange, Texas, in collaboration with Qatar Petroleum.

The onsite releases of approximately 60 million tons CO2e from crackers and related power plants are only part of these facilities’ climate impacts. These complexes demand methane for electricity, and gases for cracking. In 2019, crackers in the U.S. relied on 22 power plants, together consuming 6 million tons of methane per year. This amount was enough to heat and power more than 4 million homes, more than 3% of the households in the nation. It was also enough to cause the leakage of 204,000 tons of methane from fracking, processing and transporting this gas to the cracker, equivalent to 5.1 million tons of carbon dioxide releases using a 100-year conversion rate, or more than 17.1 million tons per year in the short term.

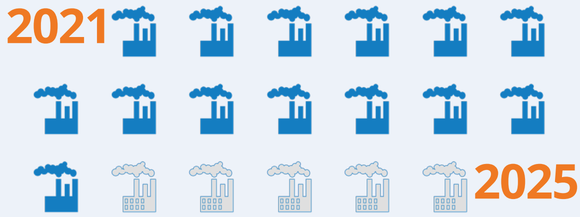
As of October 2021, there were 35 cracker facilities in the U.S. with a combined 45 million tons-per-year capacity, an increase of 14 locations and 19 million tons from 2005. Five more crackers are either under construction or planned with a combined 9.1 million tons additional cracking capacity.



This map is a mix of existing, under construction, and proposed new cracker facilities. Under Construction: Corpus Christi, Texas; Monaca (Beaver County), Pennsylvania. Planned: Welcome (St. James Parish), Louisiana; Mead Township, Ohio; and, Orange, Texas.

SECTION 4

OTHER PLASTICS FEEDSTOCK MANUFACTURING



This stage of plastics production -- manufacturing other plastics feedstocks -- releases more than 28 million tons of CO2e gases per year, equal to the emissions of 14 average-sized coal-fired power plants in 2020. Expansion has the potential to add another 10 million tons by the year 2025, equal to 5 coal-fired power plants. Emissions associated with extraction and delivery of feedstocks are accounted for in earlier stages.

Crackers are not the only engines of plastics production. Other primary ingredients come from factories that process coal, methanol, chlorine, and ammonia. As with crackers, these chemical facilities' climate impacts are abundant.

In the U.S., coal-to-plastics is accomplished through a process called "gasification." Coal is blown through with oxygen and steam while also being super-heated. Purified products of the coal gasification process include methanol and acetic acid, which are then used in the manufacture of synthetic yarns, films and other plastics. Only one plastics manufacturer, based in Kingsport, Tennessee, uses coal gasification to make plastics in the U.S[20]. It reported releasing more than 4.2 million tons of CO2e in 2019, ranking as one of the plastics industry's highest stand-alone sources of greenhouse gases.

Most methanol is produced from methane, not coal, and it is usually consumed as a fuel. But an increasing amount of methanol is used to make plastics. Already, at least 1.5 million tons of CO2e gases are released from methanol plants each year in support of plastics production. The industry plans to open ten new methanol plants in Louisiana and Texas; according to the Environmental Integrity Project's analysis of permits, they could emit a combined 10 million tons of CO2e releases per year.

Not many people associate chlorine with plastic, but this element is a major feedstock – and it, too, comes with an outsized burden of emissions. Common plastics such as vinyl, siding, piping, insulation, street signs, and hand bags, are made from combinations of ethylene and chlorine. An energy intensive process called chlor-alkali electrolysis extracts chlorine from a very common material (salt brine)[21]. In 2019, ten plastics facilities with chlor-alkali plants reported having released more than 10 million tons of CO2e in that year alone.

Another emissions-producing feedstock for plastics is ammonia[22], which is used in the manufacture of plastic adhesives like those that bind pieces of wood into countertops and other solid surfaces. Argonne National Laboratory scientists calculate that 2.6 tons of CO2e gases are released per ton of ammonia[23]. About 2% of the plastics industry's estimated emissions come from ammonia production, estimated at 4.5 million tons CO2e per year[24].

SECTION 5

POLYMER AND ADDITIVE PRODUCTION

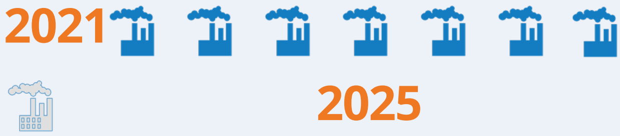
Polymer production happens when the building blocks of plastics—the simple hydrocarbon molecules created from gas, coal, or oil—are formed into chains called polymers. These polymers are then combined in various ways to make plastics with different characteristics[25].

Powerful catalysts speed this process. Many catalysts are quite toxic. Phillips 66's patented catalyst, for instance, incorporates hexavalent chromium, a well-established carcinogen associated with lung cancer and nasal and sinus cancer. The "Phillips catalyst" is the industry standard for polymerization of many plastics[26]. Ascend Performance Materials in Alvin, Texas, uses a very unexpected type of catalyst – radioactive depleted uranium – and then dumps the waste in landfills on-site[27].

Polymerization uses a lot of energy. "Certain types of plastic are more energy intensive to produce than others, because of the additives or catalysts needed in the manufacturing process," notes the Environmental Integrity Project. "Like in cracking, emissions and energy requirements vary by production method and efficiency, as well as plant age and the types of emissions controls used."[28]

Overall, North American polymer producers (the vast majority in the U.S.) manufactured more than 60 million tons of polymers in 2021[29]. Most polymers are produced in facilities that have crackers or other primary chemical production units, which are included in the above discussions. Some only receive primary chemicals, so their releases can be identified and counted separately (about 13 million tons CO2e per year).

Most plastics are combinations of polymers and additives. Additives provide dizzying arrays of qualities to plastics[30]. They make plastics colorful, catsup bottles squeezable, plastic cups stiff, and garments stain- and water-repellent using PFAS chemicals.



Polymer and additive manufacturers released at least 14 million tons of CO2e gases in 2020, equal to the emissions of at least 7 average-sized coal-fired power plants. Expansion has the potential to add at least another 2 million tons per year by 2025, the equivalent of one average coal-fired power plant's emissions. These figures do not include emissions from plants that also produce feedstocks accounted for above.

Additives protect plastics from catching fire, breaking down in sunlight, and being eaten by bacteria or fungi. Some additives are fragrances that mask the smell of plastic. A 2021 study identified more than 8,000 additives used in combination with polymers to create plastics[31].

By volume – and climate impact – carbon black is one of the most significant additives. More than 90% of it is used to fill, strengthen and color plastics, especially synthetic rubber tires. Carbon black is manufactured by decomposing oil or natural gas. The combined climate impact of the ten largest carbon black plants is about equal to a typical coal-fired power plant in 2020, two million tons CO2e per year.

Some PFAS additives are thousands of times more potent greenhouse gases than carbon dioxide[32]. Plastics companies use fluorochemicals for stain repellency in textiles, and as blowing agents in insulation. Fluorochemical production sites run by Chemours in Washington, West Virginia, and Fayetteville, North Carolina, Daikin in Decatur, Alabama, and Honeywell in Baton Rouge, Louisiana serve the plastics industry. Combined, they reported releasing 3 million tons of greenhouse gases in 2019. See Appendix 1 for further details.

Accounting for the full climate impact of plastics additives production is just beginning. EPA requires some, but not all, manufacturers to provide information about some, but not all, greenhouse gases. Many additives plants are either overseas or too small to report releases to EPA's inventory, and thus,are not reflected in the official record nor in this report's estimates.

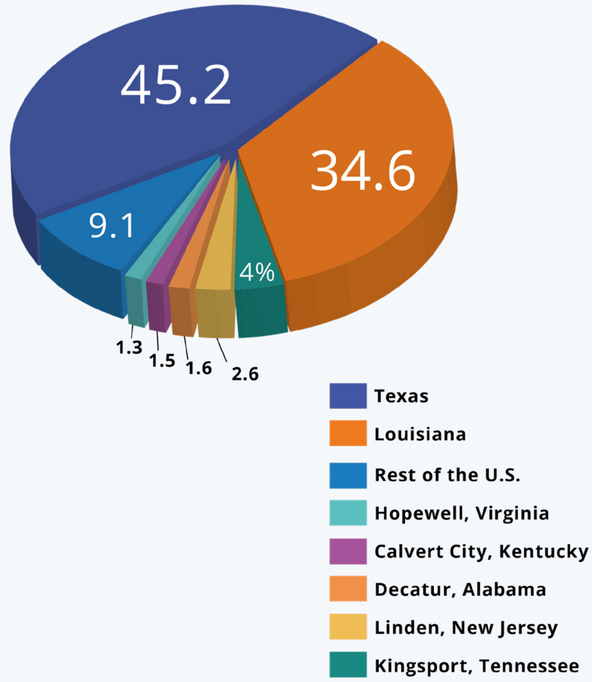
The health impacts of emissions released by the plastics industry are disproportionately felt by low-income communities and people of color. The industry releases more than 90% of its reported climate pollution into 18 communities, mostly along the coastlines of Texas and Louisiana. People living within 3 miles of these petrochemical clusters earn 28% less than the average U.S. household and are 67% more likely to be people of color.

Community leaders demand federal action to halt Formosa Plastics' plans to build the world's largest cracker in St. James Parish, Louisiana, on March 9, 2021. Several months later, the Army Corps of Engineers ordered a full environmental impact assessment. Photo courtesy of Healthy Gulf.

Communities where the plastics industry releases over 1 million tons per year CO2E

1. Houston/Baytown, Texas - 20.2 million tons (2020)
2. Freeport, Texas - 16.6 million tons
3. Norco/Taft, Louisiana - 10.3 million tons
4. Plaquemine/St. Gabriel, Louisiana - 8.6 million tons
5. Beaumont/Port Arthur, Texas - 7.8 million tons
6. Lake Charles, Louisiana - 7.7 million tons
7. Baton Rouge, Louisiana - 6.3 million tons
8. Geismar, Louisiana - 5.2 million tons
9. Point Comfort, Texas - 4.8 million tons
10. Kingsport, Tennessee - 4.1 million tons
11. Corpus Christi, Texas - 4 million tons
12. Orange, Texas - 3.3 million tons
13. Linden, New Jersey - 2.7 million tons
14. Longview, Texas - 2.4 million tons
15. Victoria, Texas - 1.9 million tons
16. Decatur, Alabama - 1.4 million tons
17. Hopewell, Virginia - 1.3 million tons
18. Calvert City, Kentucky - 1.27 million tons

GEOGRAPHIC SHARE OF TONS OF CO2E PER YEAR FROM PLASTICS PRODUCTION (2019)



SECTION 6

EXPORTS AND IMPORTS

This stage of plastics production -- exports from the U.S. of raw materials and imports into the U.S. of the same – causes the release of at least 51 million tons or more of CO2e gases overseas per year, equal to emissions from 25 average-sized coal-fired power plants in 2020. At a modest 3.9% compound annual growth rate, this trade will release 6 million tons more CO2e per year by 2025, equivalent to three coal-fired power plants. This estimate does not account for many plastics products that move to or from the United States.

Plastics is a globalized industry with the United States as its center. A thorough analysis must account for emissions from the extraction, processing, and transportation of gases and other U.S.-made feedstocks for plastics production in other countries. A comprehensive account would also consider the fates of plastics products shipped from the U.S., especially when they become waste and are incinerated. This report is a starting point for such a record.

Whether released in this country or abroad, emissions are adding to the burden of climate change experienced worldwide.

Much of the plastics industry in the U.S. is export-oriented, starting with fracking. More and more of the extraction of ethane gases is for overseas plastics producers. Ships called "Very Large Ethane Carriers" exist for the sole purpose of delivering this gas from the United States. India's Reliance Industries imports almost half (45%) of all ethane exported from the U.S. by ship. Soon after ethane is extracted from beneath the state of Texas, it becomes single-use plastics packaging in Asia. Shipments from Texas to India weighed 1.5 million metric tons, which was 45% of the 3.4 million metric tons exported overall from the U.S. by vessel in 2020. An additional 3.2 million metric tons of ethane is sent by pipeline to Canada and Mexico.

Overseas, consumption of the 6.6 million tons of exported ethane in crackers will release about 10 million tons of CO2e gases per year.

"In the U.S., leaks from the extraction of this ethane for export are estimated at 171,000 tons of methane per year. These releases will have a climate impact equivalent of more than four million tons CO2e over 100 years, or 14 million tons in the next twenty years."

Moving these enormous quantities of ethane to the other side of the world is itself carbon intensive. In 2020, Very Large Ethane Carriers emitted an estimated 660,000 metric tons of CO2e while making deliveries to plastics factories in Asia and Europe[33].

Exports of plastic resins made in the U.S. result in substantial overseas emissions, especially when they are burned. **In 2020, more than 25 million tons of plastic resins – 41% of all those produced in North America – made their way overseas[34].** These exports will lead to about 12 million tons of greenhouse gas emissions from incineration[35].

The offshoring of plastics production for U.S. consumption adds to the industry's climate impact. For some products, U.S. manufacturers have shut down their domestic production in favor of China's coal-based plastics. Today, about half of all floors sold in the U.S. are imported vinyl tile and carpet[36]. These imports contain an estimated 6.7 million tons of plastic (see Appendix 2. Methodology). The manufacturing of this much plastic releases about 17 million metric tons of greenhouse gas overseas[37].

The U.S. plastics industry also imports petrochemical feedstocks. In 2020, the U.S. plastics industry imported more than 6.7 million tons of primary chemicals such as p-xylene and benzene; their overseas production created an estimated 7.5 million tons of greenhouse gas emissions[38].

THE ONGOING PLASTICS BUILDOUT IS NOT JUST FOR U.S. CONSUMPTION. PLASTICS COMPANY FLEETS DELIVER ETHANE GAS FROM THE U.S. TO CRACKERS IN INDIA, CHINA, AND EUROPE. SOON AFTER ETHANE IS EXTRACTED FROM BENEATH THE STATE OF TEXAS, IT BECOMES SINGLE-USE PLASTIC PACKAGING IN ASIA.

The Ethane Topaz, a "Very Large Ethane Carrier" owned by plastics corporation Reliance Industries of India, plies waters off Texas. Photo by Bill Word.

In the application of spray polyurethane foam, petrochemicals are reacted and create plastic envelopes around buildings.

SECTION 7

OFF-GASSING: FOAMED PLASTIC INSULATION

The use of blowing agents in plastic insulation releases at least 27 million metric tons of carbon dioxide equivalent gas per year from buildings and landfills[43]. This is as much CO2e as was released by 13 average-sized coal-fired power plants in 2020. Regulations may eliminate the use of these fluorochemicals in plastics but releases will continue from existing insulation for years.

Fluorochemical gases in plastic insulation help to trap heat inside buildings. The same gases, when released, trap heat in Earth's atmosphere.

About one-quarter (25%) of fluorochemical gases inside plastic insulation migrate into the air within the first year of installation, and continue to off-gas for at least 50 years. The blowing agents used in foamed plastic insulation are emitted from buildings in which it is installed and landfills where the foamed plastic insulation is dumped. Those that remain in the walls of housing stock will continue to linger and leak for decades.

Plastic insulation fluorochemicals are outsized contributors to climate change. Two gases used in plastic insulation - HFC-134a and HFC-245fa - have CO2 equivalents of 1,430 and 1,030, respectively[39]. Honeywell manufactured over 25,000 metric tons of these chemicals in 2015[40].

EPA is mandating a transition to alternative blowing agents, but for now, these gases remain standard. Blowing agents in foam insulation installed this year will offgas for decades. At current estimated rates of production, about 7 million tons of CO2e will be released within the first year of installation. The balance (about 20 million tons) will be released more gradually, over decades, from buildings as the insulation degrades and from landfills where most insulation is buried.[41]

This report's estimate of 27 million metric tons of CO2e releases from insulation in the U.S. likely is a substantial underestimate. According to a United Nations technical committee report, banning the use of fluorocarbons from foam insulation would avoid "over 1 billion tons of carbon dioxide equivalents."

There are many types of insulation that work well and do not release fluorochemical gases. The Energy Efficiency for All initiative lists fiberglass, cellulose and many other affordable and less damaging options. It notes, "Fortunately, there are solutions thanks to innovative new products and improved versions of well-known products coming to market."[42]

SECTION 8

"CHEMICAL RECYCLING"

From city halls to state houses, the U.S. plastics industry fights bans on products like plastic shopping bags, bottles, and polystyrene foam. Instead, vested producers argue that recycling is the solution. After decades of public relations promoting the use of post-consumer plastics, however, recycling rates have stagnated at little more than 8.5%[44]. Nevertheless, the promise of recycling is one of the chief drivers of plastic consumption at the consumer level. Individuals who hope and believe their purchases to be recyclable are less likely to hesitate to consume them.

The industry does all it can to maintain this belief despite its failure to deliver on its recycling promises. Today, the industry is marketing what it calls "Chemical Recycling." This process is often marketed as a new or "advanced" method of surmounting the "technical challenges" posed by plastics recycling. At base, however, most of the methods applied are techniques for turning plastics into fuel, not new plastic products.

Most "chemical recycling" proposals are plans to use high inputs of energy to turn waste back into hydrocarbon feedstocks such as naphtha (a flammable, hydrocarbon liquid). The most common process is pyrolysis in which a high-heat furnace melts solid plastic into liquid feedstocks[45]. On a laboratory level, such techniques sometimes work. On the ground, the presence of contaminants, difficulties with sorting, and other factors make the process unfeasible – and the energy inputs required to carry out the procedure are exorbitant.

Public agencies are aware of this deception. A December 2020 EPA assessment of the fates of 35 "chemical recycling" companies revealed the following:

- Only six were operating at commercial or demonstration scale
- Two resulted in multi-million-dollar fraud judgments against their CEOs.
- Several other projects ended with lawsuits and settlements for unpaid services and breaches in contracts.
- Only one gasification plant and two pyrolysis facilities are currently in operation at a commercial scale in the U.S., using fractions of municipal waste as feedstock[46].

There is minimal "chemical recycling" of plastic wastes. However, expansion of pyrolysis and other so-called "advanced recycling" has the potential to add up to 18 million tons per year by the year 2025, equal to the emission of nine coal-fired power plants in 2020."

Perhaps the most established "chemical recycling" project, New Hope Energy in Tyler, Texas, converts 340,000 tons of plastic waste to low-grade fuel. It sells "pyrolysis oil" to ChevronPhillips Chemical and other petrochemical companies[47]. New Hope Energy says plastics "are worth 3-4 times more as fuel than as scrap."[48] At full capacity, New Hope Energy pyrolysis could release more than 16,000 tons of carbon dioxide each year. Subsequent burning of the waste oil could release an additional 200,000 tons of annual global warming gases per year.

Chemical industry executives on occasion concede that burning post-consumer waste instead of reusing it in new products, "is not recycling," but still promote chemical recycling as something other than turning plastic waste into fuel[49].

Overall, the plastics industry's proposed "chemical recycling" projects, if built, could emit more than 18 million tons of greenhouse gases per year.

"ADVANCED RECYCLING IS A SET OF REPROCESSING TECHNOLOGIES THAT THE PLASTICS INDUSTRY IS TOUTING AS AN ENVIRONMENTAL SAVIOR – AND SEES AS KEY TO ITS OWN CONTINUED GROWTH AMID MOUNTING GLOBAL PRESSURE TO CURB THE USE OF PLASTIC."

– Reuters Special Report, July 29, 2021[50]

SECTION 9

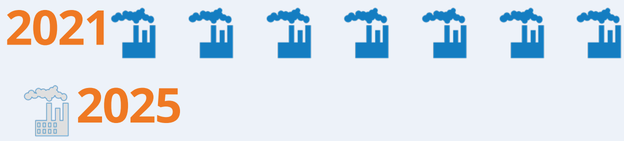
MUNICIPAL WASTE INCINERATION

When plastic waste cannot be recycled it is often incinerated, a practice which carries the highest climate impact of any sanctioned waste management practice, including pyrolysis[51]. The petrochemical industry labels these as "waste-to-energy recovery facilities," because they generate a limited amount of electricity. That phrase, much like "chemical recycling," masks their primary function: to burn garbage.

Seventy-five incinerators in the U.S. burn household trash and other municipal waste streams, and a growing proportion of this is composed of plastic. In 2018, about 17% of incinerated trash was plastic by weight, double what it was in 1990[52]. As the concentration of plastics in municipal waste increases, so too does the amount of carbon dioxide released into the atmosphere from incineration. It is estimated that garbage incinerators in the United States emitted more than 14 million tons of CO2e from the burning of plastics in 2018, a figure that now likely exceeds 15 million tons per year[53].

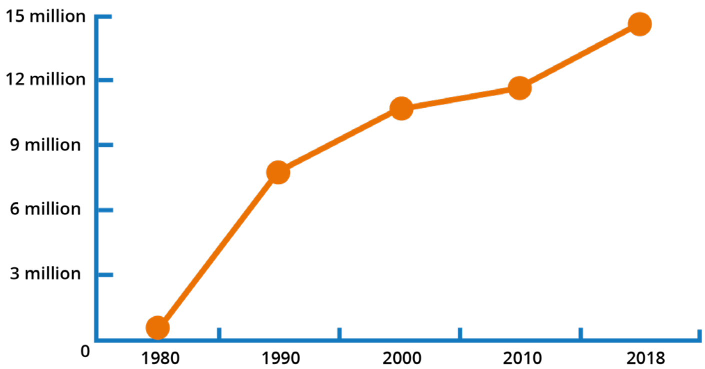
There are vital gaps in regulations for municipal waste incinerators. Most were constructed in the 1980s and 1990s, with state and federal permits that were issued when the proportions of plastics in household garbage were lower. Many of the elements burned in incinerators are unmonitored and unregulated. EPA does not collect information about the release of potent greenhouse gases from burning consumer products that contain fluoropolymers, for example, which includes textiles and insulation. This class of chemicals includes some of the planet's most potent gases, some with more than 10,000 times the global warming impact of carbon dioxide[54].

Another gap in understanding follows EPA's endorsement of the burning of plastic garbage – carpets, plastic bags, and car parts – in other facilities, especially cement kilns. EPA categorizes plastic waste burned by these facilities to be "non-waste fuel," and also as landfill diversion and recycling. **It does not keep track of how much plastic "non-waste fuel" is burned in cement kilns[55].**



This stage of plastics disposal -- the burning of plastic waste in municipal waste incinerators in the U.S. -- releases an estimated 15 million tons of CO2e gases per year, equivalent to releases from 7 average-sized coal-fired power plants in 2020. As proportions of plastics in waste increase, so too will the greenhouse gas released by incinerators; by 2025, these additions could equal those of an average coal-fired power plant.

C02E RELEASED FROM U.S. PLASTIC WASTE INCINERATION MEASURED IN TONS



Graph produced by Material Research L3C using US Environmental Protection Agency data.

Bales of household plastic waste from Europe fell from a cargo ship into Penobscot Bay, Maine, in December 2020. A nearby municipal waste incinerator in Maine burned the rest of the 10,000 ton shipment, releasing an estimated 23,200 tons of carbon dioxide and other pollution. Photo by Eliza Vallette.

SECTION 10

PLASTICS IN THE WATER

"EVERY FISH IN THE GREAT LAKES HAS PLASTIC IN IT."

- Dr. Chelsea Rochman, Professor of Ecology and Evolutionary Biology, University of Toronto

One of the most significant endpoints for waste plastics is the ocean. Approximately 15 million tons of plastic waste entered the ocean in 2018, and experts predict that dumping and pollution will exceed 40 million tons annually by 2025[56]. Because plastics never biodegrade, marine settings can become a sort of tomb for discarded goods. With the exception of the fraction that has washed back to shore, the majority of plastic that has ever entered the ocean remains there today. Its gradual fragmentation has concerning effects on marine biosystems, and on the climate itself.

Plastic polymers are stable but they are not inert. Though the vast majority of plastics in the ocean has settled toward the ocean floor, millions of tons of bottles, bags, and other discarded materials gyrate around the Pacific, Atlantic, and Indian Oceans, where the churn of the water and the glare of the sun accelerate the process of fragmentation. As they weather – and particularly as they absorb UV rays – plastics release a variety of chemicals, as well as measurable amounts of greenhouse gases. The quantity released depends on multiple variables, from the type and surface area of the plastic to the amount of solar radiation, but what is clear is that the type that releases the most is also the most common (accounting for 36% of plastics in existence), and is the most abundant in the world's oceans.

This plastic, polyethylene, is also the most prolific emitter of methane and ethane gases. Its comparatively weak chemical structure includes more exposed hydrocarbon branches, which break free more easily than other plastic polymers when the material is exposed to sunlight. Studies indicate that many plastics will not emit gas when kept in the dark, but this is not always the case for polyethylene. Once exposed to sunlight, it will continue to emit greenhouse gases even after it is moved to the dark.

The sheer quantity of polyethylene – and its tendency, as a lightweight material, to float more easily on the surface – presents a daunting challenge. Low density polyethylene (LDPE), its most common form, is used for six pack rings, plastic wrap, cereal bags, squeeze bottles, and countless other applications. The material is ubiquitous, and is estimated to be the most common form of plastic pollution in surface ocean waters worldwide[57].

The amount of surface area presented by floating LDPE trash itself accelerates the production of hydrocarbons, a process that scientists expect to continue with no predictable end[58].

Diane Wilson shows some of the plastic pellets that Formosa Plastics in Point Comfort, Texas, regularly discharges into Lavaca Bay. Wilson led a successful lawsuit bringing record penalties against Formosa. Photo courtesy of Healthy Gulf.

"PLASTICS NEVER REALLY GO AWAY. THEY JUST BREAK DOWN OVER AND OVER AND OVER AGAIN UNTIL THEY BECOME SMALLER AND SMALLER FROM SUNLIGHT AND OTHER ENVIRONMENTAL FACTORS."

- Dianna Parker, Communications Specialist, National Oceanic and Atmospheric Administration.

ENDNOTES

1 Zheng, J., Suh, S. Strategies to reduce the global carbon footprint of plastics. Nat. Clim. Chang. 9, 374–378 (2019). https://doi.org/10.1038/s41558-019-0459-z

2 Basel Action Network. US Export Data. August 2021. https://www.ban.org/plastic-waste-project-hub/trade-data/usa-export-data

3 Basel Action Network. US Plastic Trade Metrics. March 15, 2021. PowerPoint presentation. https://baselactionnetwork.app.box.com/v/plastic-waste-trade-data/file/787370174143

4 Global Alliance for Incinerator Alternatives. Discarded: Communities on the Frontlines of the Global Plastic Crisis. April 2019. 24 pp. https://wastetradestories.org/wp-content/uploads/2019/04/Discarded-Report-April-22-pages.pdf

5 Intergovernmental Panel on Climate Change. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press. https://www.ipcc.ch/report/ar6/wg1/

6 Taylor, Joanna. More than a billion seashore animals may have been cooked to death in Canada heatwave. The Independent. July 6, 2021. https://www.independent.co.uk/climate-change/news/seashore-animals-death-heatwave-canada-b1878937.html

7 Wamstead, D., and Seth Feaster, "IEEFA U.S.: The coal-to-renewables transition takes off. Pre-Biden changes underscore coming 10-year wave of coal plant retirements." Institute for Energy Economics and Financial Analysis, May 5, 2021. https://ieefa.org/ieefa-u-s-the-coal-to-renewables-transition-takes-off/

8 Environmental Protection Agency. "Overview of Greenhouse Gases." https://www.epa.gov/ghgemissions/overview-greenhouse-gases#CH4-reference Accessed September 21, 2021.

9 Concerned Health Professionals of New York, & Physicians for Social Responsibility. Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction) (7th ed. December 2020). https://www.psr.org/wp-content/uploads/2020/12/fracking-science-compendium-7.pdf

10 ICF International. "Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM), Containers, Packaging, and Non-Durable Good, Materials Chapters." U.S. Environmental Protection Agency, February 2016. https://www.epa.gov/sites/default/files/2016-03/documents/warm_v14_containers_packaging_non-durable_goods_materials.pdf.

11 Howarth, Robert, and Mark Jacobson. "How Green Is Blue Hydrogen?" Energy Science & Engineering (August 12, 2021): 1–12. https://onlinelibrary.wiley.com/doi/epdf/10.1002/ese3.956.

12 United States Department of Energy. Ethane Storage and Distribution Hub in the United States, November 2018. https://www.energy.gov/sites/prod/files/2018/12/f58/Nov%202018%20DOE%20Ethane%20Hub%20Report.pdf.

13 Blum, Jordan. "Petrochemical Plants Turn Ethane into Building Blocks of Plastic," September 14, 2018. https://www.houstonchronicle.com/business/energy/article/Geology-makes-region-the-focal-point-13225097.php

14 Environmental Protection Agency. 2019 Greenhouse Gas Emissions from Large Facilities (database). https://ghgdata.epa.gov/ghgp/main.do

ENDNOTES

15 Ditzel, Ken, Rob Fisher, and Kaustuv Chakrabarti. "Economic Benefits of the Mountain Valley Pipeline Project in West Virginia." FTI Consulting, October 2, 2015. http://www.mountainvalleypipeline.info/wp-content/uploads/2019/03/Mountain_Valley_Pipeline_West-Virginia_Report_02Oct2015.pdf

16 Environmental Integrity Project. "Emissions Increase Database and Pipelines inventory." May 3, 2021. https://environmentalintegrity.org/oil-gas-infrastructure-emissions/

17 Congressional Research Center. "Natural Gas Liquids: The Unknown Hydrocarbons," October 26, 2018. https://www.everycrsreport.com/files/20181026_R45398_4689ed62d838a75154157954d35550a07aab3b11.pdf and ICF International. "Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM), Containers, Packaging, and Non-Durable Good, Materials Chapters." U.S. Environmental Protection Agency, February 2016. https://www.epa.gov/sites/default/files/2016-03/documents/warm_v14_containers_packaging_non-durable_goods_materials.pdf

18 Muse Stancil. "Prospect for the Development of a Fairbanks Petrochemical Industry," June 2004. https://www.arlis.org/docs/vol1/AlaskaGas/Paper/Paper_MS_2004_ProspectDevPetrochemIndustry.pdf

19 Calculation: Formosa's two power plants on the Point Comfort site consumed 38,000,000 mmbtu (38 trillion btu) natural gas in 2019, according to U.S. Energy Information Administration records. two power plants: https://www.eia.gov/opendata/qb.php?category=4309&sdid=ELEC.PLANT.CONS_TOT_BTU.10554-NG-ALL.A and https://www.eia.gov/opendata/qb.php?category=6812&sdid=ELEC.PLANT.CONS_TOT_BTU.56708-NG-ALL.A The average household, according to the EIA, consumes 90 million btu of energy per year. U.S. Energy Information Administration. U.S. Energy Information Administration. "Residential Energy Consumption Survey Data Show Decreased Energy Consumption per Household," June 6, 2012. https://www.eia.gov/todayinenergy/detail.php?id=6570.

20 Eastman. History. Accessed September 17, 2021. https://www.eastman.com/Company/About_Eastman/History/Pages/Introduction.aspx.

21 Vallette, Jim. (2018). Chlorine and building materials: A global inventory of production technologies, markets, and pollution, phase 1: Africa, the Americas and Europe. Washington D.C.: Healthy Building Network. https://healthybuilding.net/reports/18-chlorine-building-materials-project-phase-1-africa-the-americas-and-europe.

22 Rossi and Blake calculate that 10% of ammonia is used in plastics production. Rossi, Mark, and Ann Blake. Plastics Scorecard, Evaluating the Chemical Footprint of Plastics. Clean Production Action, 2014. https://www.bizngo.org/images/ee_images/uploads/plastics/plastics_scorecard_2015_2_25e.pdf.

23 Liu, Xinyu, Amgad Elgowainy, and Michael Wang. "Life Cycle Energy Use and Greenhouse Gas Emissions of Ammonia Production from Renewable Resources and Industrial By-Products." Green Chemistry, no. 17 (2020). https://pubs.rsc.org/en/content/articlelanding/2020/gc/d0gc02301a.

24 Calculations based on volumes reported in U.S. Energy Information Administration. "Natural Gas Weekly Update," April 1, 2021. https://www.eia.gov/naturalgas/weekly/archivenew_ngwu/2021/04_08/

25 ICF International. "Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM), Containers, Packaging, and Non-Durable Good, Materials Chapters." U.S. Environmental Protection Agency, February 2016. https://www.epa.gov/sites/default/files/2016-03/documents/warm_v14_containers_packaging_non-durable_goods_materials.pdf

ENDNOTES

26 Lunk, Hans-Joachim. "Discovery, Properties and Applications of Chromium and Its Compounds." ChemTexts 1, no. 6 (February 13, 2015). https://link.springer.com/article/10.1007/s40828-015-0007-z

27 United States Nuclear Regulatory Commission. "Ascend Performance Materials." Complex Materials Sites, March 24, 2021. https://www.nrc.gov/info-finder/decommissioning/complex/ascend-performance-materials.html.

28 Bernhardt, Courtney and Eric Schaeffer, Chapter 5. Refining and Manufacture, in Plastic & Climate: The Hidden Costs of a Plastic Planet, 2019. https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf

29 American Chemistry Council. The Resin Review - 2021, 2021 https://store.americanchemistry.com/products/the-resin-review-2021

30 American Chemistry Council. "Chemistry of Plastics." Chemistry in America. Accessed September 15, 2021. https://www.americanchemistry.com/chemistry-in-america/chemistry-in-everyday-products/plastics

31 Wiesinger, Helene, Zhanyun Wang, and Stefanie Hellweg. "Deep Dive into Plastic Monomers, Additives, and Processing Aids." Environmental Science & Technology 55, no. 13 (June 21, 2021): 9339–9351. https://pubs.acs.org/doi/10.1021/acs.est.1c00976.

32 United States Environmental Protection Agency. "Understanding Global Warming Potentials." Greenhouse Gas Emissions. Accessed September 15, 2021. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

33 Based on weight of exports and trade route distances. One metric ton of ethane equals 17.6 barrels. Barrels by country obtained from the United States Energy Information Administration. "Exports by Destination." Petroleum & other liquids, August 31, 2021. https://www.eia.gov/dnav/pet/pet_move_expc_a_EPLLEA_EEX_mbbl_a.htm. Ethane carrier emissions calculated using Distance and Carbon Estimator. Pier2Pier.com. https://www.pier2pier.com/Co2. Accessed September 21, 2021.

34 American Chemistry Council. The Resin Review - 2021, 2021, https://store.americanchemistry.com/products/the-resin-review-2021 and International Trade Commission Dataweb records. See methodology appendix for further details.

35 On average, globally, 17% of plastics are incinerated, per Moon, Doun and Jeffrey Morris. Chapter 6 "Plastic Waste Management" in Plastic & Climate: The Hidden Costs of a Plastic Planet, 2019. https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf According to the Energy Transitions Partnership, incinerating a pound of plastic waste causes the release of 2.7 pounds of carbon dioxide equivalent gas per pound of waste. Energy Transitions Commission. Mission Possible, Getting Net Zero Carbon Emissions from Harder-to-Abate Sectors by Mid-Century, 2020. https://www.energy-transitions.org/wp-content/uploads/2020/08/ETC-sectoral-focus-Plastics_final.pdf

36 STATS: Flooring Sales Trend Slightly Lower in 2020." Floor Covering News, May 17, 2021. https://www.fcnews.net/2021/05/stats-2020-flooring-sales-industry-stats/

37 According to the Energy Transitions Partnership, on average 2.5 pounds of CO2e are generated in the production of plastics. This ratio is applied to the proportion of plastics in a typical "luxury vinyl tile" floor, the most common flooring sold in the U.S.

38 Based on the weight of imports of primary chemicals, as provided by the U.S. International Trade Commission's DataWeb database, and the proportions of these chemicals that are used in plastics as determined by Rossi and Blake's Plastics Scorecard.

39 EPA Center for Corporate Climate Leadership. "GHG Emission Factors Hub." United States Environmental Protection Agency. Accessed September 21, 2021. https://www.epa.gov/

ENDNOTES

climateleadership/ghg-emission-factors-hub
40 Chemical Data Reports filed by Honeywell in 2016 under EPA's CDR program. Chemical Data Reporting. "2016 CDR Data." Accessed September 21, 2021. https://www.epa.gov/chemical-data-reporting/access-cdr-data
41 EPA. Draft Regulatory Impact Analysis for Phasing Down Production and Consumption of Hydrofluorocarbons (HFCs). May 2021. https://www.epa.gov/sites/default/files/2021-05/documents/draft_regulatory_impact_analysis_for_phasing_down_production_and_consumption_of_hydrofluorocarbons.pdf
42 Energy Efficiency for All. "Making Homes Healthier." Accessed September 15, 2021. https://www.energyefficiencyforall.org/issues/making-homes-healthier/
43 Based on American Chemistry Council projections of capacity
44 Staub, Colin. "Plastics recovery flat amid 2018 recycling rate downturn." Plastics Recycling Update, November 18, 2020. https://resource-recycling.com/plastics/2020/11/16/plastics-recovery-flat-amid-2018-recycling-rate-downturn/
45 Tabrizi, Shanar, Andrew Neil Rollinson, Marieke Hoffmann, and Enzo Favoino. Understanding the Environmental Impacts of Chemical Recycling. Zero Waste Europe, 2020. https://zerowasteeurope.eu/wp-content/uploads/2020/12/zwe_jointpaper_UnderstandingEnvironmentalImpactsofCR_en.pdf.
46 Thorneloe, S., K. Weitz, J. Stephenson, and O. Kaplan. Assessment of Municipal Solid Waste Energy Recovery Technologies. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-20/142, 2020. https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=350673&Lab=CESER
47 SCS Global Services. "ISCC PLUS Certificate," March 5, 2021. https://certificates.iscc-system.org/cert-pdf/ISCC-PLUS-Cert-US201-70600949.pdf.
And "New Hope Energy Signs Agreement with Chevron Phillips Chemical." New Hope Energy, April 2, 2021. https://newhopeenergy.com/news/f/new-hope-energy-signs-agreement-with-chevron-phillips-chemical.
48 "FAQs." New Hope Energy. Accessed September 15, 2021. https://newhopeenergy.com/faq
49 Tullo, Alexander. "Should Plastics Be a Source of Energy?" Chemical & Engineering News, September 24, 2018. https://cen.acs.org/environment/sustainability/Should-plastics-source-energy/96/i38
50 Brock, Joe, Valerie Volcovici, and John Geddie. "Special Report-The Recycling Myth: Big Oil's Solution for Plastic Waste Littered with Failure." Reuters, July 29, 2021. https://www.reuters.com/article/us-environment-plastic-oil-recycling/special-report-the-recycling-myth-big-oils-solution-for-plastic-waste-littered-with-failure-idUSKBN2EZ1EF
51 Ahazmi, Hatem, Faris H. Almansour, and Zaid Aldhafeeri. "Plastic Waste Management: A Review of Existing Life Cycle Assessment Studies." Sustainability, 2021. 13(10), 5340. https://doi.org/10.3390/su13105340 and Takada, Hideshige and Lee Bell . "Plastic Waste Management Hazards: Waste-to-Energy, Chemical Recycling, and Plastic Fuels." International Pollutants Elimination Network. 2021. https://ipen.org/sites/default/files/documents/ipen-plastic-waste-management-hazards-en.pdf and Pew Trusts. "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution." 2020. https://www.pewtrusts.org/-/media/assets/2020/10/breakingtheplasticwave_mainreport.pdf
52 United States Environmental Protection Agency. "National Overview: Facts and Figures on Materials, Wastes and Recycling." July 14, 2021.
https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-over-

ENDNOTES

view-facts-and-figures-materials#Recycling/Composting
53 Author's calculations based on EPA WARM Model (2.32 CO2E metric tons per short ton mixed plastic combustion), per Exhibit 5-15, United States Environmental Protection Agency. "Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM): Containers, Packaging, and Non-Durable Good Materials Chapters." February 20216. https://www.epa.gov/sites/default/files/2016-03/documents/warm_v14_containers_packaging_non-durable_goods_materials.pdf; and United States Environmental Protection Agency. "National Overview: Facts and Figures on Materials, Wastes and Recycling: Combustion With Energy Recovery Tonnages, 1960-2018." July 14, 2021. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#Recycling/Composting.
54 Stratkova, Jita, Marketa Moller, Karolina Brabkova, et al. "Throwaway Packaging, Forever Chemicals: European-wide Survey of PFAS in disposable food packaging and tableware." Arnika Association, Czech Republic, 2021. 54 pp. https://www.researchgate.net/publication/351774362_THROWAWAY_PACKAGING_FOREVER_CHEMICALS_European-wide_survey_of_PFAS_in_disposable_food_packaging_and_tableware
55 Note: EPA's WARM provides conversion factors for carpet combustion, based on municipal solid waste incinerators. It does not provide factors for carpet combustion in cement kilns or other combustion units. United States Environmental Protection Agency, "Waste reduction Model." July 29, 2021. https://www.epa.gov/warm
56 Plastic & Climate The Hidden Costs of a Plastic Planet, 2019. https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-Executive-Summary-2019.pdf.
57 Frias JPGL, Otero V, Sobral P. Evidence of microplastics in samples of zooplankton from Portuguese coastal waters. Mar Environ Res. 2014;95: 89–95. pmid:24461782; Hidalgo-Ruz V, Gutow L, Thompson RC, Thiel M. Microplastics in the marine environment: A review of the methods used for identification and quantification. Environ Sci Technol. 2012;46: 3060–3075. pmid:22321064; Reisser J, Shaw J, Wilcox C, Hardesty BD, Proietti M, Thums M, et al. Marine plastic pollution in waters around Australia: Characteristics, concentrations, and pathways. PLoS One. 2013;8: 1–11. pmid:24312224
58 Royer, S. J., Ferrón, S., Wilson, S. T., & Karl, D. M. (2018). Production of methane and ethylene from plastic in the environment. PloS one, 13(8), e0200574