PLASTICS:

THE LAST STRAW FOR BIG OIL?

AN INVESTOR BRIEF ON THE RISKS OF OVERINVESTMENT IN PETROCHEMICALS

AS YOU SOW®

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EXECUTIVE SUMMARY

The energy sector is facing significant demand reduction for fossil fuel products as the world transitions to cleaner sources of electricity and fuel in response to the climate crisis. To hedge against shrinking demand from the power and transportation sectors, oil and gas companies are allocating significant resources to boost petrochemical operations. Investors must now ask whether relying on high demand growth assumptions for plastics and other petroleum-based products will indeed pay off or whether the industry's growing Environmental, Social, and Governance (ESG) issues will continue to plague this attempted shift.

This report explores a range of financial and ESG risks associated with the plastic and petrochemical sectors that are worthy of increased investor scrutiny and engagement in order to assess the petrochemical investment strategies of companies promoting this growth. Ten key takeaways for investors include:

1. **Significant Investment Is at Risk of Stranding** – $56 billion of U.S. and $400 billion of global investment into additional plastic production capacity are at risk of becoming stranded as ESG concerns push the world toward a net-zero, circular economy.
2. **U.S. Petrochemical Project Financials Are in Question** – Overcapacity, a narrowing cost advantage for U.S. ethane-based production over naphtha, a potential for reduced demand growth, and other factors (including from COVID-19) are already squeezing U.S. ethylene margins and causing some projects to delay or cancel, raising questions regarding the viability of future expansion plans.
3. **High Petrochemical Demand Growth Assumptions Rely on High Plastic Consumption in the Global South** – Currently half of U.S. polyethylene (PE) production is exported, and future resin production is becoming increasingly reliant on export markets. Demand for plastics in Organisation for Economic Co-operation and Development (OECD) countries has saturated and even started to decrease, leaving the bulk of predicted demand growth for plastics to developing countries in the Global South.
4. **Plastic Pollution Has Risen to the Top of the World's Most Pressing Crises** – In 2016, the world mismanaged 41% of its plastic waste. If the status quo continues, this will grow to 56% by 2040. Momentum is growing across consumers, markets, governments, and other stakeholders to reduce plastic consumption, hold plastic producers responsible for pollution of land and seas, and transition from a linear plastic model to a circular economy.
5. **There Is No Silver Bullet Solution to Plastic Pollution, and Absolute Reduction of Plastic Production is Key** – Many approaches are needed, with elimination, reuse, and substitution of alternative materials expected to play major roles. All such strategies necessitate a reduction in virgin plastic production, raising questions about industry's inflated demand expectations. While investments in traditional, mechanical recycling as well as in newer technologies like bioplastics or "advanced" recycling are also needed, significant concerns and challenges limit the role these technologies are likely play, and they should be viewed with caution.
6. **Fossil-Based Plastics and Other Petrochemicals Have a Significant Climate Footprint** – The petrochemical industry emits greenhouse gasses (GHG) across its entire supply chain, from extraction of fossil fuels through the end-of-life of petroleum-based products. The plastic lifecycle alone may be on track to consume 19% of the world's remaining carbon budget by 2040 under business-as-usual growth.

7. **Integrated Oil and Gas Company Disclosure of Petrochemical Climate Impacts Is Limited** – As traditional sector boundaries continue to blur for companies involved in the fossil fuel and chemical sectors, increased clarity and transparency is needed to assure that all relevant GHG emissions are accounted for by the companies responsible. When assessing company GHG disclosures and targets, it is critical for investors to understand which activities are "in scope" and which are left unaddressed.

8. **Physical Climate Risks Exacerbate Concerns on Investment in Petrochemical Expansion** – Climate change is strengthening the frequency and strength of extreme storms, especially in the Gulf Coast, where much of the petrochemical production capacity in the U.S. is being built. Such storms bring significant economic costs to company assets and facilities as well as public health risks to the communities that surround them from increased chemical releases and pollution resulting from such events. Investors should be informed on the asset-level physical risks of company operations and which assets face the most risk. At a minimum, companies should provide detailed geographic and locational information for each company asset.

9. **Petrochemical Operations Pollute Communities** – Petrochemical facilities and related infrastructure use and emit dangerous chemicals, many with documented negative health or environmental effects. Emissions often surpass permitted levels, and aggregated impacts have led to the creation of "Cancer Alley" – an area of Louisiana where proximity to over 200 petrochemical plants exposes communities to high levels of dangerous chemicals and cancer rates.

10. **Long-Standing Environmental Justice Concerns Threaten the Petrochemical Industry's Social License to Operate** – People of color are twice as likely to live within a fence-line zone of a petrochemical facility. Industry's plans to continue development of petrochemical activities in Black and low-income communities face growing opposition and legal challenges from grassroots organizations and community groups.

As all such issues continue to evolve, robust investor engagement is critical to assure petrochemical investment risks are not overlooked. By better incorporating these financial and ESG concerns into the assessment of petrochemical expansion plans, investors can avoid locking in infrastructure that may be unnecessary, harmful, and uneconomic.

INTRODUCTION

The loss of value for the oil and gas industry caused by COVID-19's economic slow-down highlights the coming structural difficulties for oil and gas companies from an accelerating clean energy transition. As the industry faces a decline in demand for oil and gas, some companies have offered a theory of growing global demand for petrochemicals, especially plastics, as justification for continued exploration and extraction of fossil fuels. Oil companies describe this growth as aligned with society's goals to responsibly decarbonize. Yet, in a world that is awash with plastic production and waste, facing a continued climate crisis, and seeking environmental justice and equity, the proposed expansion of plastic production raises red flags for investors and requires enhanced scrutiny.

While plastics and other petrochemical products are predicted to overtake the transport sector as the largest driver of future global oil demand, fossil fuel companies risk overinvestment in the space. Companies that rely on growing demand for plastics and other petrochemicals must justify these plans in the face of a range of global structural changes that may deflate these elevated demand growth expectations. Peeking behind the veil of the industry narrative exposes the abundant ESG risks and externalities presented across every stage of the plastic lifecycle.

This report provides investors an overview of the landscape of risks posed by the petrochemical sector and its planned plastic buildout, including stranded assets, climate change impacts, plastic pollution of land and oceans, the greenwashing of "circular" solutions, public health impacts, and a loss of social license to operate. Critical questions are provided in each of the risk areas to encourage productive investor engagement with companies that are lacking transparency in their disclosures. More comprehensive disclosures in the areas described will add clarity and enable better accountability in this evolving field.

SHIFTING ECONOMICS

MAPPING DEMAND FOR PETROCHEMICALS AND PLASTICS

Until recently, the petrochemical sector accounted for a relatively limited portion of total global demand for oil. In 2017, petrochemicals made up only 14% of oil demand, compared to 56% from the transportation sector.[1] However, as the clean energy transition proceeds to reduce fossil fuel use in the transportation and power sectors, the petrochemical sector is taking center stage, and questions are arising as to whether this sector's demand growth will live up to expectations.

While the petrochemical sector is complex, intersects every sector of society, and covers over 100,000 registered products with varying production volumes,[2] 90% of the sector's consumption of fossil fuels comes from the production of seven primary chemicals: ammonia, methanol, ethylene, propylene, benzene, toluene, and mixed xylenes.[3] Ammonia is the building block of all nitrogen-based fertilizers, and methanol is a major intermediary for the production of chemicals like formaldehyde.[4] Benzene, toluene, and mixed xylenes fall under the umbrella of a group of chemicals called "aromatics" and together with ethylene and propylene, called "light olefins", make up what the International Energy Agency (IEA) refers to as High Value Chemicals because they are often co-produced in the same unit processes.[5] Light olefins are the primary chemicals that underpin the vast majority of the plastic industry.

Demand for fossil fuels in the petrochemical sector results from the need for fossil-based feedstocks (accounting for more than half) and for energy to process said feedstock.[6] Of global feedstocks used in the sector, 74% come from oil and 25% from gas.[7] The major feedstocks for plastic production – ethane and naphtha – are both classified as oil. As such, demand for fossil-based plastics can be measured and forecasted by using data on the sector's oil demand.

1. IEA, *The Future of Petrochemicals*, October 2018, https://www.iea.org/reports/the-future-of-petrochemicals, 27.
2. Peter G. Levi and Jonathan M. Cullen, "Mapping Global Flows of Chemicals: From Fossil Fuel Feedstocks to Chemical Products," *Environmental Science & Technology* 52, no. 4 (January 2018), https://pubs.acs.org/doi/10.1021/acs.est.7b04573.
3. IEA, The *Future of Petrochemicals*, https://www.iea.org/reports/the-future-of-petrochemicals, 27.
4. Ibid, 24
5. Ibid, 25, 32.
6. Ibid.
7. Ibid.

Carbon Tracker's 2020 report *The Future's Not in Plastics*[8] broke down recent oil demand to find that in 2017, plastic production accounted for two-thirds (10 million barrels per day (Mbpd)) of petrochemical oil demand with single-use plastics accounting for one-third of total plastic produced.[9] Looking forward, the IEA has predicted that petrochemicals will be the largest driver of net oil demand growth through 2030.[10] More recently, BP's 2020 *Energy Outlook* forecasts that, although global oil demand will decrease, plastics will dominate the growth in non-combusted use of oil through 2050 under business-as-usual.[11] Such analyses highlight the significant role the oil and gas industry expects plastics will play in the coming years and the interconnectedness of the two industries.

FOSSIL FUEL'S BIG BET AND ITS UNDERLYING ASSUMPTIONS

The IEA notes that demand for plastics has historically grown faster than any other bulk material, with high-income countries using almost 20 times more plastic per capita than low-income countries.[12] Now that demand for plastics in OECD countries has saturated and even started to decrease, the outlook that industry is relying on for substantial growth in fossil fuel demand assumes that developing economies will follow the same growth trajectory of plastic consumption as did high-income countries (approximately 4% annual growth in demand since 2010).[13]

The largest segment of demand growth will occur in plastic packaging that is predominantly single-use.

This outlook has several implications worthy of scrutiny from investors, including that the largest segment of demand growth will occur in plastic packaging that is predominantly single-use[14] and that the profitability of new plastic resin production in the U.S. is substantially reliant on exports.[15] The oversupplied U.S. market is already heavily reliant on export markets, with about half of U.S. PE production currently being exported,[16] including into areas like China and India that are also expanding their own petrochemical production capacity.[17] If demand for plastics does not occur in developing economies as forecast, export margins will decrease and further shrink the profitability of new U.S. plastic resin production. Recent reports of the plastic industry's efforts to create new plastic markets in the Global South underscore these risks.[18]

8. Carbon Tracker Initiative, *The Future's Not in Plastics: Why Plastics Demand Won't Rescue the Oil Sector* (September 2020), https://carbontracker.org/reports/the-futures-not-in-plastics/.
9. Ibid.
10. IEA, *The Future of Petrochemicals*, https://www.iea.org/reports/the-future-of-petrochemicals, 11.
11. BP Energy Economics, *Energy Outlook: 2020 Edition*, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2020.pdf, 38-39.
12. IEA, *The Future of Petrochemicals*, https://www.iea.org/reports/the-future-of-petrochemicals, 18-19.
13. Carbon Tracker Initiative, *The Future's Not in Plastics*, https://carbontracker.org/reports/the-futures-not-in-plastics/.
14. Roland Geyer, Jenna R. Jambeck, and Kara Lavender Law, "Production, Use, and Fate of All Plastics Ever Made," *Science Advances* 3, no. 7 (July 2017): e1700782, https://doi.org/10.1126/sciadv.1700782.
15. Planet Tracker, "Plastics," https://planet-tracker.org/tracker-programmes/materials/plastics/.
16. Renzo Pipoli, "New Polypropylene Plant in Texas to Relieve Momentary Shortage but Later Add to Glut," September 15, 2020, https://www.reutersevents.com/downstream/supply-chain-logistics/new-polypropylene-plant-texas-relieve-momentary-shortage-later-add-glut.
17. IEA, *The Future of Petrochemicals*, https://www.iea.org/reports/the-future-of-petrochemicals.
18. Hiroko Tabuchi, Michael Corkery and Carlos Mureithi, "Big Oil Is in Trouble. It's Plan: Flood Africa with Plastic," August 30, 2020, https://www.nytimes.com/2020/08/30/climate/oil-kenya-africa-plastics-trade.html.

Over-optimistic demand assumptions, paired with deepening overcapacity from the previous surge in plastic investment, threaten the economic feasibility of planned and existing projects—a situation exacerbated by the COVID-19 pandemic (see box at right). The potential for these expensive projects and assets to become economically "stranded" is a rapidly materializing risk.

Impact of COVID-19 on Petrochemicals

The COVID-19 pandemic shocked energy markets as economic activity and travel rapidly halted in early 2020 – slashing global demand for oil and petrochemicals like plastics. The shock sent crude prices plummeting,[19] which transformed ethylene cost curves and caused margins for natural gas-based ethylene producers in the U.S. to shrink; margins are expected to stay below 2015 levels until 2028.[20] Petrochemical demand impacts seen across end-use value chains have been irregular, with sharp declines in automotive and construction, but packaging remaining more robust with increases in healthcare and delivery services.[21] There are various projections as to how far global petrochemicals demand will fall and when it will rebound. Deloitte forecasts demand to rebound in late 2021.[22] A McKinsey & Co analysis provides other more conservative global recovery scenarios where demand would recover to 2019 levels by 2023.[23] While much uncertainty remains, the shock has exposed clear vulnerabilities and risks to overly optimistic industry assumptions.

Surging Investment and Overcapacity

Driven by the Shale Revolution's production of cheap ethane (the predominant plastic feedstock in the U.S.) over the last decade,[24] fossil fuel investment has poured into what has been called the Plastic Production Corridor (Corridor) along the U.S. Gulf Coast in Texas and Louisiana (see Figure 1).[25] Beginning in 2012, Dow Inc. led the initial wave of American investment in the Corridor by investing $6 billion in projects over the next several years. This buildout included the recommissioning of an ethylene cracker in St. James, Louisiana, and the completion of the world's largest ethylene production plant (2 million tonnes annually) in Freeport, Texas.[26] Other companies have invested similarly, with $97 billion going toward 229 new or expansion projects built in the U.S. since 2010.[27] Much of this investment occurred in the Corridor, which is currently home to 89% of U.S. production capacity of PE and polypropylene (PP)[28] and 95% of ethylene.[29] Globally, Carbon Tracker estimates that $200 billion of plastic production capacity had been invested by the end of 2019.[30]

Despite the surge of investment into the Corridor over the last decade, major producers are continuing investment into additional production capacity.[31] For example, Chevron Phillips Chemical Company (CPChem) is planning an $8 billion joint venture (JV) cracker plant with Qatar Petroleum[32] and Exxon a $10 billion JV cracker plant with

19. Wood Mackenzie, "Coronavirus Hits the Petrochemicals Industry with Two Major Shockwaves," April 3, 2020, https://www.woodmac.com/news/opinion/coronavirus-hits-the-petrochemicals-industry-with-two-major-shockwaves/.
20. Collin Eaton and Saabira Chaudhuri, "Firms Like Dow Bet Billions on Plastics. Now There's a Glut," *The Wall Street Journal*, October 15, 2020, https://www.wsj.com/articles/firms-like-dow-bet-billions-on-plastics-now-theres-a-glut-11602754200.
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22. Duane Dickson, David Yankovitz, and Aijaz Hussain, "Building Resilience in Petrochemicals: Navigating Disruption and Preparing for New Opportunities," Deloitte Insights, October 26, 2020, https://www2.deloitte.com/us/en/insights/industry/oil-and-gas/building-resilience-petrochemical-market.html.
23. Malik et al., "The impact of COVID-19," https://www.mckinsey.com/industries/chemicals/our-insights/the-impact-of-covid-19-on-the-global-petrochemical-industry.
24. IEA, "The US Shale Revolution Has Reshaped the Energy Landscape at Home and Abroad, According to Latest IEA Policy Review," September 13, 2019, https://www.iea.org/news/the-us-shale-revolution-has-reshaped-the-energy-landscape-at-home-and-abroad-according-to-latest-iea-policy-review.
25. Planet Tracker, "Plastics," https://planet-tracker.org/tracker-programmes/materials/plastics/.
26. Heather Doyle, "DowDuPont Project Managers Share Success behind $6 bn US Gulf Coast Initiative," June 14, 2018, https://www.reutersevents.com/downstream/engineering-and-construction/dowdupont-project-managers-share-success-behind-6-bn-us-gulf-coast.
27. American Chemistry Council, *Shale Gas Is Driving New Chemical Industry in the U.S.*, https://www.americanchemistry.com/Shale_Gas_Fact_Sheet.aspx.
28. Planet Tracker, "Plastics," https://planet-tracker.org/tracker-programmes/materials/plastics/.
29. Ted Auch, "Channels of Life: The Gulf Coast Buildout in Texas," Fractracker Alliance, December 23, 2020, https://www.fractracker.org/2020/12/channels-of-life-the-gulf-coast-buildout-in-texas/.
30. Carbon Tracker Initiative, *The Future's Not in Plastics*, https://carbontracker.org/reports/the-futures-not-in-plastics/.
31. Reuters Events, "Whitepaper: North America & Beyond—2020 Downstream Market Outlook," October 14, 2019, https://www.reutersevents.com/downstream/engineering-and-construction/whitepaper-north-america-beyond-2020-downstream-market-outlook.
32. Chevron Phillips Chemical, "Chevron Phillips Chemical and Qatar Petroleum Announce Plans to Jointly Develop U.S. Gulf Coast Petrochemical Project," July 9, 2019, https://www.cpchem.com/media-events/news/news-release/chevron-phillips-chemical-and-qatar-petroleum-announce-plans-jointly.

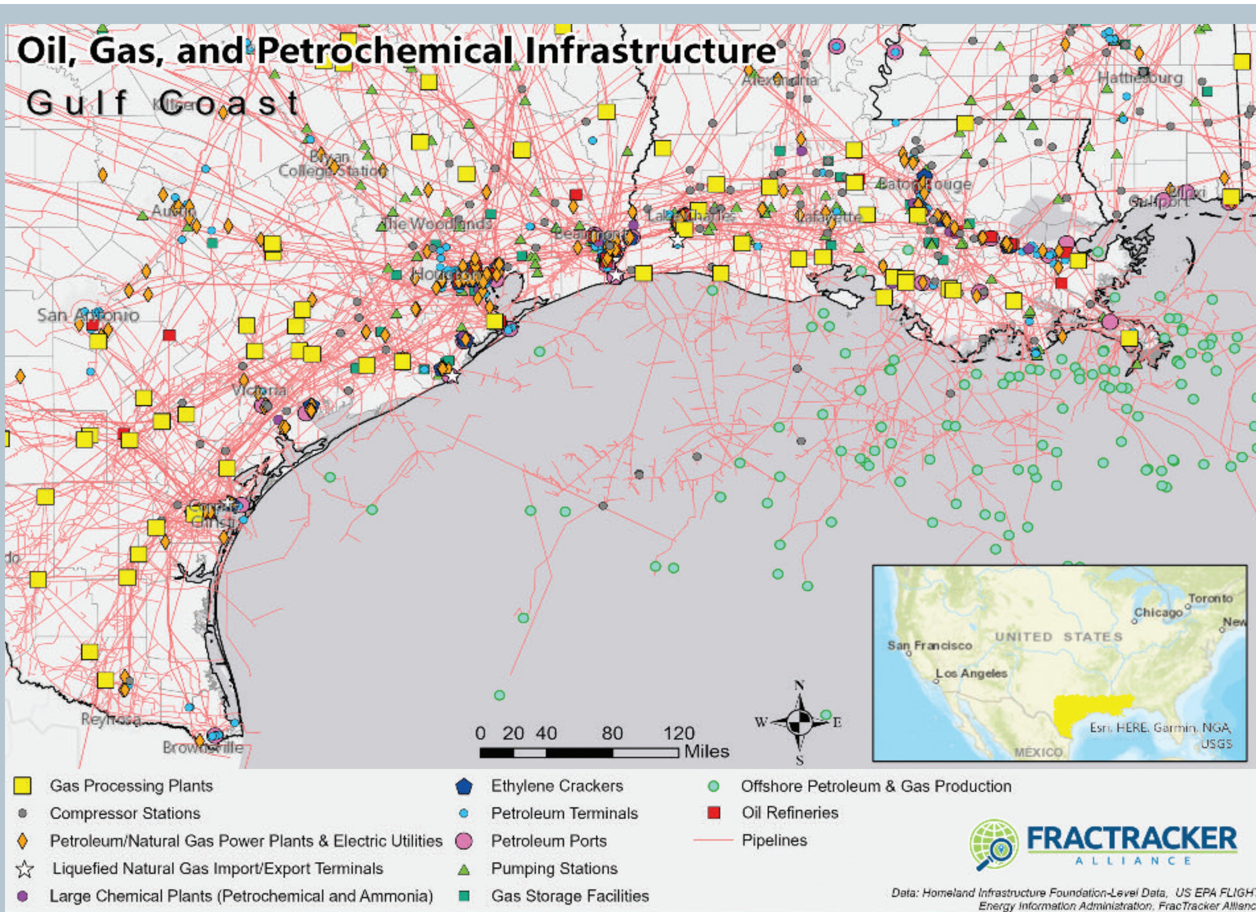

Figure 1: Oil, Gas, and Petrochemical Infrastructure Along the Gulf Coast

SOURCE: FracTracker Alliance, "National Energy and Petrochemical Map," https://www.fractracker.org/2020/02/national-energy-petrochemical-map/#tab-id-3-active

SABIC[33] through its "Growing the Gulf Campaign."[34] Planet Tracker estimates that an additional $40 billion of capacity expansion is set to occur by 2025 in the Corridor alone.[35] Globally, Carbon Tracker estimates an additional $400 billion will be invested in plastic production capacity by 2025.[36]

In the U.S., another region is beginning to see significant petrochemical development: the Ohio River Valley (see Figure 2). The Marcellus and Utica shale plays in West Virginia, Eastern Ohio, and Western Pennsylvania form the "Shale Crescent" along the Ohio River. Wet gas from these abundant Northeastern shale formations accounts for 85% of natural gas production growth between 2008 and 2018.[37] Easy access and geographic proximity to low-cost feedstocks and a large segment of the North American plastic resin demand market, which is located in the Northeast, gave rise to industry's hopes for a second U.S. petrochemical hub to rival the Gulf Coast's Corridor.[38] This hope is reflected in the Trump Administration's Department of Energy report – *Appalachian Energy and Petrochemical Renaissance* – that promises unfettered economic growth for the region as well as energy

33. Gulf Coast Growth Ventures, http://www.gulfcoastgv.com/index.php.
34. ExxonMobil, "Growing the Gulf," https://corporate.exxonmobil.com/Locations/United-States/Growing-the-Gulf.
35. Planet Tracker, *Stormy Outlook for US Plastics Refiners: Risk of Stranded Assets in the Gulf of Mexico*, Resins Briefing Paper (November 2020), https://planet-tracker.org/tracker-programmes/materials/plastics/#stormy-outlook.
36. Carbon Tracker Initiative, *The Future's Not in Plastics*, https://carbontracker.org/reports/the-futures-not-in-plastics/.
37. Reuters Events, "Whitepaper," https://www.reutersevents.com/downstream/engineering-and-construction/whitepaper-north-america-beyond-2020-downstream-market-outlook, 19-20.
38. Ibid, 18-20.

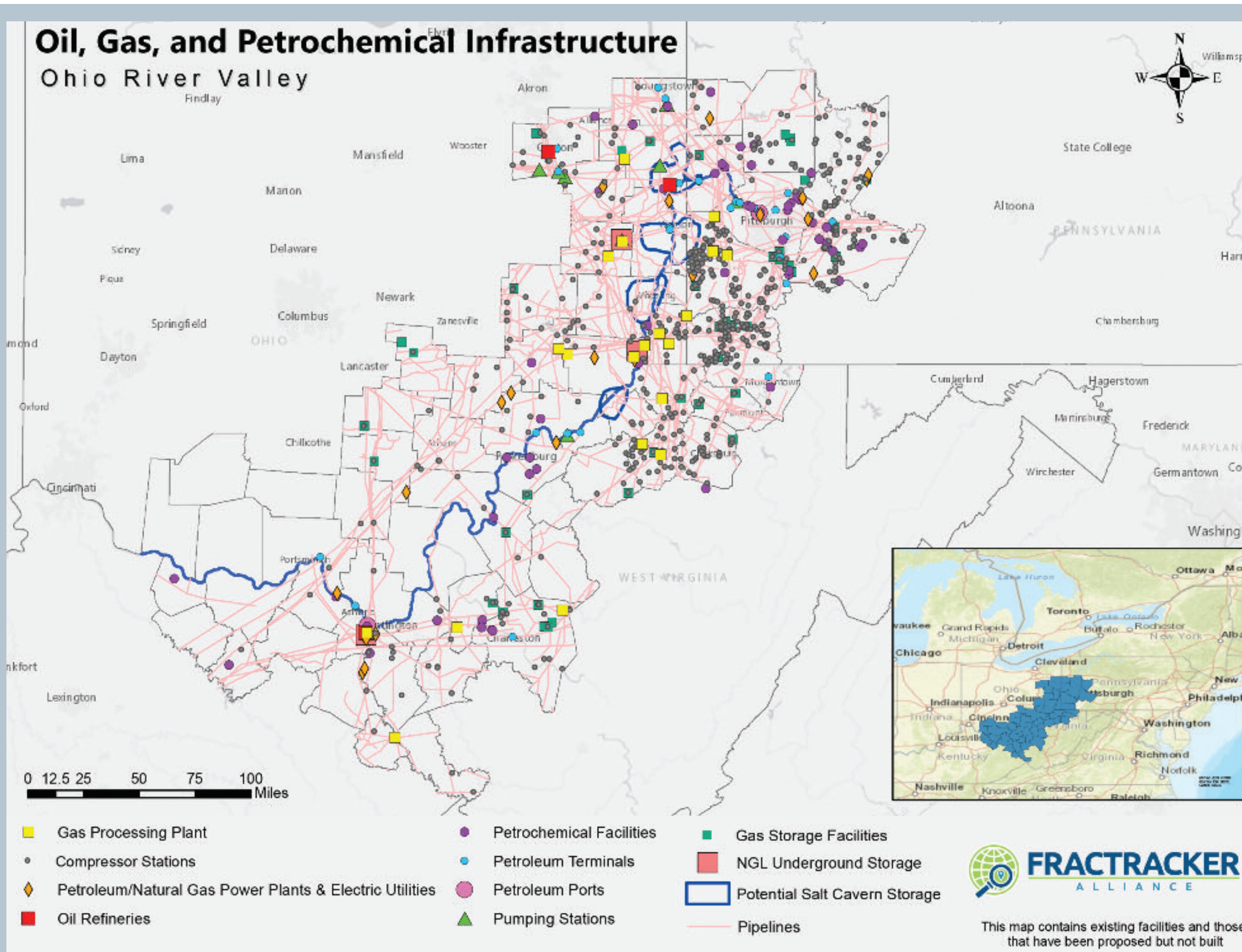

Figure 2: Oil, Gas, and Petrochemical Infrastructure in the Ohio River Valley

SOURCE: FracTracker Alliance, "National Energy and Petrochemical Map," https://www.fractracker.org/2020/02/national-energy-petrochemical-map/#tab-id-3-active

independence for the country from the buildout of an Ohio River Valley petrochemical hub.[39] The report uses industry-sponsored economic impact studies predicated on the construction of five new ethane crackers, the DOE-sponsored Appalachian Storage Hub,[40] two dehydrogenation plants (propylene production), and 500 miles of new pipeline in the region. However, a weakening outlook and deepening supply glut has caused most of this infrastructure plan to be delayed or cancelled.[41]

Plastic production in the U.S. has been in a concerning state of overcapacity since around 2014.[42] Despite this, significant investments into supply additions continued while demand struggled to keep pace (as discussed below), causing reduced utilization rates and ethylene prices even before the COVID-19 pandemic.[43] Indeed,

39. U.S. Department of Energy, *The Appalachian Energy and Petrochemical Renaissance: An Examination of Economic Progress and Opportunities*, June 2020, https://www.energy.gov/sites/prod/files/2020/06/f76/Appalachian%20Energy%20and%20Petrochemical%20Report_063020_v3.pdf.
40. Eric Dixon, "Critical Condition: 'The Shale Crescent' and the Dream of an Appalachian Petrochemical Boom," Blog Posts, Ohio River Valley Institute, March 4, 2021, https://www.energy.gov/sites/prod/files/2018/12/f58/Nov%202018%20DOE%20Ethane%20Hub%20Report.pdf.
41. Ibid.
42. Carbon Tracker Initiative, *The Future's Not in Plastics*, https://carbontracker.org/reports/the-futures-not-in-plastics/.
43. Renzo Pipoli, "Chemical Margins Tighten More as Markets Try to 'Digest' New Output," Downstream, Reuters Events, January 28, 2020, https://www.reutersevents.com/downstream/supply-chain-logistics/chemical-margins-tighten-more-markets-try-digest-new-output.

industry's plastic dream kept its ambitions high, with 2019 being the peak year for cracker project startups[44] and analysts forecasting growth in ethylene capacity between 4 and 7% per year between 2019 and 2024 (pre-COVID).[45,46] With COVID-related demand impacts, the plastic supply glut has continued to deepen.[47]

Declining Margins

Historically, U.S. plastic producers retained a major feedstock advantage from cheap ethane in shale deposits in comparison to naphtha-based producers in Asia and Europe.[48] At its peak in late 2014, Gulf Coast margins for ethylene were $558 per tonne. This has shrunk to $127 per tonne in 2020 and is predicted to continue to squeeze down to $50 per tonne by 2022.[49] The deepening supply glut certainly bears some of the blame here. However, the COVID-19 pandemic has exposed additional cracks in the North American feedstock advantage.[50]

As mentioned, the high price of oil has historically disadvantaged plastic producers that use oil-based naphtha as a feedstock. However, the low-price oil environment created by the COVID-19 pandemic narrowed the previous cost advantage for ethane-based production compared to naphtha.[51,52] This, in addition to the recent introduction of crude-oil-to-chemicals technologies in international operations, threatens to continue chipping away at the margins for U.S. producers.[53,54] Already, petrochemical projects in the U.S. have stalled or lost value this year.[55] While industry purports margins will quickly recover post-pandemic, analysts like Wood Mackenzie predict they will stay well below 2015 levels until around 2028.[56] The price volatility of fossil fuels adds a degree of uncertainty to these predictions. For example, the price of crude temporarily spiked during the devastating winter storm in Texas in February, but the spike is unlikely to hold.[57]

The inextricable connection between the plastic and fossil fuel industries may become a double-edged sword for future profitability. The feedstocks for plastics are currently considered "derivatives" because they are not the primary product of fossil fuel extraction, which carries a heavy cost. Historically, fossil fuel demand for transportation and power have covered the costs of extraction. However, as the clean energy transition materializes and petrochemicals become the main revenue stream for the oil and gas industry, producers may have to internalize these costs of extraction into the cost of plastic production – an additional squeeze on margins.[58]

44. Alexander H. Tullo, "Petrochemical Makers Look Ahead to Uncertain Decade," *C&EN Chemical & Engineering News* 98, no. 10 (March 16, 2020), https://cen.acs.org/business/petrochemicals/Petrochemical-makers-look-ahead-uncertain/98/i10.
45. Carbon Tracker Initiative, *The Future's Not in Plastics*, https://carbontracker.org/reports/the-futures-not-in-plastics/.
46. Reuters Events, "Polyethylene Investment Still Surging in North America," Downstream, October 2, 2019, https://www.reutersevents.com/downstream/engineering-and-construction/polyethylene-investment-still-surging-north-america.
47. Dickson et al., "Building Resilience," https://www2.deloitte.com/us/en/insights/industry/oil-and-gas/building-resilience-petrochemical-market.html.
48. Ibid.
49. Eaton and Chaudhuri, "Firms Like Dow Bet," https://www.wsj.com/articles/firms-like-dow-bet-billions-on-plastics-now-theres-a-glut-11602754200.
50. Jinjoo Lee, "Covid-19 Shakes Up Plastics World Order," *The Wall Street Journal*, October 15, 2020, https://www.wsj.com/articles/covid-19-shakes-up-plastics-world-order-11602759601.
51. Patrick Kirby, "How Will the Oil Price Crash Affect the Ethylene Cost Curve?," Opinion, Wood Mackenzie, March 17, 2020, https://www.woodmac.com/news/opinion/how-will-the-oil-price-crash-affect-the-ethylene-cost-curve/.
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54. Kelly Cui, "Why Crude-to-Chemicals Is the Obvious Way Forward," Opinion, Wood Mackenzie, April 27, 2020, https://www.woodmac.com/news/opinion/why-crude-to-chemicals-is-the-obvious-way-forward/.
55. Renzo Pipoli, "Project Delayed by Pandemic Retaken in 2021 at Higher Cost, While Others See Indefinite Delays," Downstream, Reuters Events, January 12, 2021, https://www.reutersevents.com/downstream/engineering-and-construction/project-delayed-pandemic-retaken-2021-higher-cost-while-others-see.
56. Eaton and Chaudhuri, "Firms Like Dow," https://www.wsj.com/articles/firms-like-dow-bet-billions-on-plastics-now-theres-a-glut-11602754200.
57. Cyril Widdershoven, "Oil Bulls Beware: This Optimism Is Unjustified," Oilprice.com, March 14, 2021, https://oilprice.com/Energy/Energy-General/Oil-Bulls-Beware-This-Optimism-Is-Unjustified.html.
58. CIEL, *Fueling Plastics: Untested Assumptions and Unanswered Questions in the Plastics Boom*, Center for International Environmental Law, n.d., https://www.ciel.org/wp-content/uploads/2018/04/Fueling-Plastics-Untested-Assumptions-and-Unanswered-Questions-in-the-Plastics-Boom.pdf, 8-9.

Demand Forecasts for Plastics in Question

In a world that is rapidly decarbonizing and increasingly repulsed by the plastic waste crisis, analysts like ICIS are recognizing the possibility of "peak-oil" and "peak-plastic" occurring within the decade.[59,60] As mentioned above, previous studies found that global plastic demand had been growing by around 4% annually since 2010.[61] While U.S. oil and gas majors and some industry analysts[62] see plastic demand growing (e.g., both Exxon and CPChem project growth at 4% or more annually,)[63,64] the IEA and BP estimated a more conservative annual growth rate of 1 to 2%, even before COVID-19.[65,66]

BP's most recent forecasts provide insight into the mounting risks for peer oil and gas majors with substantial petrochemical investments. BP, which has divested its global petrochemical assets as part of its long-term strategy to "succeed through the energy transition,"[67] not only forecast a more conservative plastic demand growth rate in its *2019 Energy Outlook*, but also modeled the impact of a global ban on single-use plastics by 2040 and found that peak oil would come before 2030.[68] BP's *2020 Energy Outlook* (during COVID) forecasts that, by 2050, oil feedstocks for plastics will be 3 Mbpd lower than its previous forecast under business-as-usual growth. BP's net-zero transition scenario forecasts oil feedstocks for plastics to be 2 Mbpd lower than current levels by 2050.[69] This implies a growth rate similar to that used in the "System Change" scenario of *Breaking the Plastic Wave*, which predicts peak virgin plastic occurring in 2027.[70]

The COVID-19 pandemic has shocked oil and gas markets. While some analysts see this demand recovering very quickly,[71] research from McKinsey & Company found that global ethylene demand might need years to recover to pre-COVID levels.[72] Considering the global ambition to transition to a world powered by clean energy and devoid of single-use plastics, which comprises a significant segment of historical demand growth and is discussed in further depth below, industry's demand growth assumptions look increasingly questionable.

59. ICIS, "Why 'Peak Oil' May Coincide with 'Peak Plastic,'" Podomatic (podcast), September 14, 2020, https://www.podomatic.com/podcasts/icisnews-europe/episodes/2020-09-14T03_54_20-07_00.
60. John Richardson, "Debate about Refinery Closures, Reconfigurations a Harmful Distraction for the Petrochemicals Business," ICIS Independent Commodity Intelligence Services, October 25, 2020, https://www.icis.com/asian-chemical-connections/2020/10/debate-about-refinery-closures-re-configurations-a-harmful-distraction-for-the-petrochemicals-business/.
61. Carbon Tracker Initiative, *The Future's Not in Plastics*, https://carbontracker.org/reports/the-futures-not-in-plastics/.
62. Grand View Research, Inc. "Plastic Packaging Market Size Worth $486.2 Billion by 2028," Cision PR Newswire, March 8, 2021, https://www.prnewswire.com/news-releases/plastic-packaging-market-size-worth-486-2-billion-by-2028--cagr-4-2-grand-view-research-inc-301242119.html, 5.
63. Carbon Tracker Initiative, *The Future's Not in Plastics*, https://carbontracker.org/reports/the-futures-not-in-plastics/, 7.
64. Reuters Events, "Whitepaper," https://www.reutersevents.com/downstream/engineering-and-construction/whitepaper-north-america-beyond-2020-downstream-market-outlook, 5.
65. IEA, *The Future of Petrochemicals*, https://www.iea.org/reports/the-future-of-petrochemicals, 18.
66. BP Energy Economics, *BP Energy Outlook, 2019 Edition*, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2019.pdf, 32-33.
67. Robert Brelsford, "BP to Divest Global Petrochemical Assets," *Oil & Gas Journal*, June 29, 2020, https://www.ogj.com/refining-processing/petrochemicals/article/14178686/bp-to-divest-global-petrochemical-assets.
68. BP Energy Economics, 2019, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2019.pdf, 35.
69. BP Energy Economics, 2020, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2020.pdf, 39.
70. The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution*, 2020, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.
71. ReportLinker, "Global Ethylene Industry," Intrado GlobeNewswire, August 21, 2020, https://www.globenewswire.com/news-release/2020/08/22/2082234/0/en/Global-Ethylene-Industry.html.
72. Malik et al., "The impact of COVID-19," https://www.mckinsey.com/industries/chemicals/our-insights/the-impact-of-covid-19-on-the-global-petrochemical-industry.

STRANDED ASSET RISK

Given growing economic questions regarding overcapacity, declining margins, and demand assumptions facing the petrochemical industry, investors must assess the potential for asset stranding as fossil fuel companies ramp up their petrochemical investments in facilities with expected useful lifetimes of multiple decades.[73] If the world fully embraces plastic reduction, substitution, and recycling opportunities, little to no more virgin plastic production capacity is needed through 2040.[74]

Evidence that such long-lived assets are risky is mounting, as several new petrochemical projects have lost value and been delayed, put on hold, or cancelled. One of the most notable is the cancellation of SABIC's billion-dollar "Project Falcon" plastic facility in Aransas Pass, Texas, due to uncertainty in the energy market.[75] SABIC, LyondellBasell, and CPChem have together delayed a total of $17 billion of major Gulf Coast petrochemical investments.[76] In the Ohio River Valley, only one project of the American Chemistry Council's (ACC) proposed petrochemical hub development plan mentioned earlier is being built (Shell's cracker in Pennsylvania), and even that project has faced significant delays.[77] Furthermore, groups like the Institute for Energy Economics and Financial Analysis (IEEFA) have cautioned that it faces a weakening outlook and numerous financial risks.[78] A similar Ohio River Valley cracker project by PTT Global Chemical has faced multiple delays, lost its major financial partner, and indefinitely postponed a final investment decision until a new economic feasibility study can be conducted.[79,80] This trend, in addition to the economic losses in the hydraulic fracturing industry,[81] raises concern for investors on the economic viability of such projects.

KEY BENCHMARKS AND BEST PRACTICES ASSOCIATED WITH SHIFTING ECONOMICS

Benchmark Questions:

– Does the company assess and disclose a scenario of continued low prices for the petrochemical feedstocks it produces, the likely impact of such a scenario to company value, and the potential for stranding of assets, including which assets are at risk of stranding?

73. Michael Pooler, "Surge in plastics production defies environmental backlash," *Financial Times*, February 11, 2020, https://www.ft.com/content/4980ec74-4463-11ea-abea-0c7a29cd66fe.
74. The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave*, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.
75. Greg Chandler, "Plans for Proposed 'Project Falcon' Plan Have Been Withdrawn," KRIS 6 News Corpus Christi, last updated November 23, 2020, https://www.kristv.com/news/local-news/plans-for-proposed-project-falcon-plan-have-been-withdrawn.
76. Eaton and Chaudhuri, "Firms Like Dow," https://www.wsj.com/articles/firms-like-dow-bet-billions-on-plastics-now-theres-a-glut-11602754200.
77. Renzo Pipoli, "Shell's Pennsylvania Cracker and Polyethylene Project to See Completion in 2022 after Covid-19 Delays," Downstream, Reuters Events, February 22, 2021, https://www.reutersevents.com/downstream/process-safety-ehs/shells-pennsylvania-cracker-and-polyethylene-project-see-completion-2022-after.
78. Tom Sanzillo and Kathy Hipple, *Shell's Pennsylvania Petrochemical Complex: Financial Risks and a Weak Outlook*, Institute for Energy Economics and Financial Analysis, June 2020, https://ieefa.org/wp-content/uploads/2020/06/Financial-Risks_Weak-Outlook_Shell-PA-Petrochemical-Complex_June-2020.pdf.
79. Jennifer Compston-Strough, "PTT Global Chemical America Delays Cracker Investment Decision Again," *The Intelligencer*, March 19, 2021, https://www.theintelligencer.net/news/top-headlines/2020/11/ptt-global-chemical-america-delays-cracker-investment-decision-again/.
80. Tom Sanzillo, Kathy Hipple, and Suzanne Mattei, *Proposed PTTGC Petrochemical Complex in Ohio Faces Significant Risks*, Institute for Energy Economics and Financial Analysis, March 2020, https://ieefa.org/wp-content/uploads/2020/03/Proposed-PTTGC-Complex-in-OH-Faces-Risks_March-2020.pdf.
81. Kathy Hipple, Clark Williams-Derry, and Tom Sanzillo, *Despite Drastic CapEx Cuts, Appalachian Frackers Spill Red Ink in Third Quarter—Again*, Institute for Energy Economics and Financial Analysis, December 2020, http://ieefa.org/wp-content/uploads/2020/12/Appalachian-Frackers-Spill-Red-Ink-in-Q3-Despite-Drastic-CapEx-Cuts_December-2020.pdf.

- Is the company's plastic production dependent on export markets? If so, how heavily?
- What oil price assumptions does the company use to calculate profit margins?
- Does the company discuss the balance sheet impacts of petrochemicals as the primary revenue stream for its fossil fuel extraction or the changing economics of extraction due to diminishing demand for primary fossil fuel products?
- How many petrochemical projects has the company proposed, and what is the ownership structure of those assets?
- Further questions tied specifically to plastic demand assumptions can be found in the following section.

Best Practice Example: In June 2020, BP agreed to a $5 billion sale of the majority of its remaining petrochemical business, consisting mainly of aromatics and acetyls, to INEOS – calling it a "deliberate step in building a BP that can compete and succeed through the energy transition."[82] This deal follows a past $9 billion sale of BP's petrochemical company, Innovene, to INEOS in 2005.[83] Although petrochemicals made up only a small portion of BP's profits, the deal was a notable break from the trend of increasing investment in petrochemicals from peers like Shell and Exxon.[84]

THE PLASTIC POLLUTION PROBLEM

Plastic pollution has become one of society's most intractable, global problems.[85] The global use of plastics has outstripped society's ability to process this waste stream. There is no part of the natural environment (including our own bodies)[86] that has not been subject to associated impacts.[87] Under business-as-usual growth, there will be more plastics in the ocean than there are fish by 2050 (by weight).[88]

82. BP, "BP Agrees to Sell Its Petrochemicals Business to INEOS," https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-agrees-to-sell-its-petrochemicals-business-to-ineos.html.
83. Hugh Hartzog and Joyce Grigorey, "What's Behind the BP and INEOS Petrochemical Deal?," Wood Mackenzie, July 6, 2020, https://www.woodmac.com/news/opinion/whats-behind-the-bp-and-ineos-petrochemicals-deal/.
84. Sarah McFarlane, "BP Exits Petrochemicals Business in $5 Billion Deal," *The Wall Street Journal*, June 20, 2020, https://www.wsj.com/articles/bp-exits-petrochemical-business-in-5-billion-deal-11593424980.
85. Veronica Penney, "Americans May Add Five Times More Plastic to the Oceans Than Thought," *The New York Times*, October 30, 2020, https://www.nytimes.com/2020/10/30/climate/plastic-pollution-oceans.html.
86. Victoria Forster, "Plastic Component Found in Human Organs," *Forbes*, August 18, 2010, https://www.forbes.com/sites/victoriaforster/2020/08/18/microplastics-found-in-human-organs-for-the-first-time/?sh=6f5e46d616f2.
87. Laura Parker, "Microplastics Have Moved into Virtually Every Crevice on Earth," *National Geographic*, August 7, 2020, https://www.nationalgeographic.com/science/2020/08/microplastics-in-virtually-every-crevice-on-earth/.
88. World Economic Forum, *The New Plastics Economy: Rethinking the Future of Plastics*, January 2016, http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf, 7.

THE CURRENT PLASTIC ECONOMY: A LINEAR, UNSUSTAINABLE MODEL

Ninety-nine percent of all plastics produced come from fossil fuels.[89] A groundbreaking study, "Production, Use, and Fate of all Plastics Ever Made," from Geyer et al. explores the history of plastic production and the effects of its current linear model (see Figure 3). Between 1950 and 2015, the world disposed of 6.3 billion tonnes of plastic polymer resins and fibers, of which only 9% have been recycled once and 1% more than once. A staggering 60% has accumulated in landfills or the natural environment.[90] A more recent report from The Pew Charitable Trusts and SYSTEMIQ found that of the world's 220 million tonnes of municipal plastic waste produced in 2016 (excluding construction, textiles, transportation, and machinery), 41% was "mismanaged" (leaked into dumpsites on land, released into oceans, and open burned), 45% was landfilled or incinerated, and only 14% was recycled.[91]

Even during the pre-production stage before plastic products are manufactured, risk of pollution exists. *As You Sow* has worked with companies to improve disclosure of pellet or "nurdle" spills, but problems remain with voluntary industry efforts.[92] Due to spills and poor handling procedures, billions of plastic pellets are swept into waterways during production or transport annually and are increasingly found on beaches and shorelines, adding to harmful levels of plastic pollution in the environment.[93]

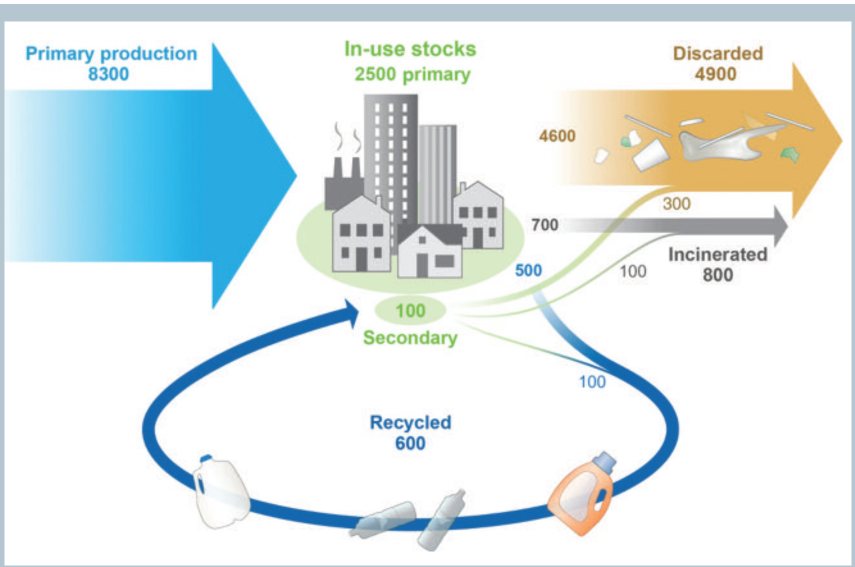

Figure 3: Global Production, Use, and Fate of Polymer Resins, Synthetic Fibers, and Additives (1950 to 2015; in million tonnes)

SOURCE: Roland Geyer, Jenna R. Jambeck, and Kara Lavender Law, "Production, Use, and Fate of All Plastics Ever Made," *Science Advances* 3, no. 7 (July 2017): e1700782, https://doi.org/10.1126/sciadv.1700782.

Of particular concern is single-use plastic packaging, which comprises about 40% of total plastic production (the largest segment).[94] Recent studies point to the same alarming conclusion: the current plastic economy is generating an increasing amount of plastic waste while effectively capturing a decreasing amount of its value – to the detriment of the planet's natural environments (land, water, air, and climate) and inhabitants. Of the small amount of plastic waste that is collected for recycling (less than 10%), most is "downcycled" to products of lower quality.[95] Given this current, linear model of production, investments into new plastic production capacity should be viewed with scrutiny.

89. CIEL, *Fueling Plastics: Fossils, Plastics, & Petrochemical Feedstocks*, Center for International Environmental Law, n.d., https://www.ciel.org/wp-content/uploads/2017/09/Fueling-Plastics-Fossils-Plastics-Petrochemical-Feedstocks.pdf.
90. Geyer et al., "Production, Use, and Fate," https://doi.org/10.1126/sciadv.1700782.
91. The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave*, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.
92. John D. Stoll, "This Proxy Season, It's Revenge of Nurdles," *The Wall Street Journal*, April 12, 2019, https://www.wsj.com/articles/this-proxy-season-its-revenge-of-the-nurdles-11555074005.
93. Eunomia, "Study Shows up to 53 Billion Plastic Pellets Could be Lost in the UK Each Year," February 12, 2016, https://www.eunomia.co.uk/eunomia-study-provides-estimate-of-uk-plastic-pellet-loss/.
94. Geyer et al., "Production, Use, and Fate," https://doi.org/10.1126/sciadv.1700782.
95. Closed Loop Partners, "A Data Visualization Tool Identifying Opportunities to Recapture Plastic in the US & Canada," 2021, https://www.closedlooppartners.com/research/us-and-canada-recycling-infrastructure-and-plastic-waste-map/?preview=true.

THE FUTURE OF PLASTICS: A CIRCULAR ECONOMY

To combat the unsustainable linear plastic economy, a momentous global effort is growing to transition toward a circular model that limits the amount of plastics produced and released into the environment and reduces dependence on fossil fuels in an economically and environmentally responsible way.

The Pew Charitable Trusts and SYSTEMIQ's landmark *Breaking the Plastic Wave* study details a comprehensive action plan to create such a transition. Promoting a set of specific global actions across a number of large-scale policy options, the study's "System Change" scenario concludes that plastic leakage into the ocean could be reduced by 80% with savings of $70 billion to the public sector by 2040 relative to business-as-usual.[96] While the sheer scale and complexity of the problem prevents the application of any one "silver bullet" solution, action is required across a variety of pathways, including potentially controversial "advanced" recycling technologies and bioplastics (covered below). However, it is crucially important to note that the largest drivers of the "System Change" scenario are achieved through elimination, reuse, and substitution with alternative materials.[97]

As the scale of plastic pollution mounts across the globe, calls for a severe reduction in the use of plastic packaging are growing, as is support for a transition to a circular economy. Both responses entail a drastic reduction in virgin plastic production.

Consumer, Corporate, and Government Commitment to the Circular Economy Is Growing

At the forefront of the transition to a circular economy for plastics is a global shift in consumer demand for more sustainable products and concern for the harmful impacts of plastic.[98] A recent IPSOS poll found that three in four global consumers "want to buy products with as little packaging as possible," and 71% of global consumers "believe that single use plastic products should be banned as soon as possible."[99] While price, quality, and brand considerations continue to outweigh packaging or environmental concern for U.S. consumers, a McKinsey & Company report found 60 to 70% of U.S. consumers said they would pay more for sustainable packaging across all end-use segments.[100]

Further evidence of momentum is demonstrated by a growing number of groups, initiatives, and companies focused on the issue. In 2016, the Ellen MacArthur Foundation launched its New Plastic Economy project, a platform for businesses and governments to make a range of major commitments focused on a circular economy for plastics.[101] Out of the more than 1,000 currently participating organizations, more than 250 businesses and 50 countries have committed to 2025 targets.[102] The Break Free From Plastic Movement, which coordinates

96. The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave*, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.
97. Ibid.
98. Leila Abboud, "Can We Break Our Addiction to Plastic? The Future of Packaging," *Financial Times*, October 31, 2019, https://www.ft.com/content/27cf9734-faa7-11e9-98fd-4d6c20050229.
99. Ipsos, *A Throwaway World: The Challenge of Plastic Packaging and Waste*, 2019, https://www.ipsos.com/sites/default/files/ct/news/documents/2019-11/a-throwaway-world-global-advisor.pdf.
100. David Feber, Anna Granskog, Oskar Lingqvist, and Daniel Nordegården, "Sustainability in Packaging: Inside the Minds of US Consumers, McKinsey & Company, October 21, 2020, https://www.mckinsey.com/industries/paper-forest-products-and-packaging/our-insights/sustainability-in-packaging-inside-the-minds-of-us-consumers.
101. New Plastics Economy, Ellen MacArthur Foundation, 2017, https://www.newplasticseconomy.org/.
102. Ellen MacArthur Foundation, *The Global Commitment 2020 Progress Report*, 2020, https://www.ellenmacarthurfoundation.org/assets/downloads/Global-Commitment-2020-Progress-Report.pdf.

grassroots efforts to press companies to change globally, also launched in 2016.[103] This organization and other NGOs add pressure through advocacy and campaigns exposing sources of plastic pollution, posing reputational risk to companies involved throughout the plastic supply chain.[104]

The Plastic Solutions Investor Alliance, launched in 2018 by *As You Sow*, has 50 investor members with a total of $2.5 trillion in assets under management and is now ramping up pressure on companies within the plastic supply chain to make meaningful commitments to materialize the transition to a circular plastic economy.[105] *As You Sow* and other investors are engaging with major consumer goods companies, seeking commitments to significantly cut absolute plastic use to reduce growing risk to their brands and value.[106] Companies are responding and differentiating themselves by taking steps to address such investor concerns.

Notable recent company commitments include the following:

- Starbucks committed to start a gradual shift from single-use to reusable packaging and cut packaging waste globally by 50% by 2030.[107]
- McDonald's set a goal to recycle all post-consumer packaging in all its restaurants by 2025.[108]
- Unilever and Procter & Gamble committed to halve their use of virgin plastic by 2025[109] and 2030,[110] respectively.
- McDonald's and Yum! Brands agreed to phase out the use of polystyrene foam.[111,112]
- Mondelēz International, Procter & Gamble, Colgate-Palmolive, Unilever, KraftHeinz, and others agreed to make all packaging recyclable, reusable, or compostable by 2025.[113]
- Burger King and Tim Hortons announced a reusable packaging pilot with Loop.[114]

Policy Trends Aimed at Reducing Plastics

Demand for change has induced mounting policy risk for the plastic industry as governmental bodies across the world recognize the rising externalities of the plastic lifecycle such as air pollution, ocean pollution, and vast cleanup costs.[115,116] The World Economic Forum reports that 170 nations have pledged to "significantly reduce"

103. Break Free From Plastic Movement, 2020, https://www.breakfreefromplastic.org/.

104. Ryan Schleeter," These 10 Companies Are Flooding the Planet with Throwaway Plastic," Greenpeace, October 9, 2018, https://www.greenpeace.org/international/story/18876/these-10-companies-are-flooding-the-planet-with-throwaway-plastic/.

105. Conrad MacKerron, "As You Sow Launches Investor Alliance to Engage Companies on Plastic Pollution," As You Sow, June 14, 2018, https://www.asyousow.org/blog/2018/6/14/as-you-sow-launches-investor-alliance-to-engage-companies-on-plastic-pollution.

106. As You Sow, "As You Sow Files Shareholder Proposals with 10 Major Consumer Goods Companies Pressing for Cuts in Use of Plastic Packaging," press release, January 14, 2021, https://www.asyousow.org/press-releases/2021/1/14/shareholder-proposals-consumer-goods-companies-plastic-packaging.

107. As You Sow, "After As You Sow Dialogue, Starbucks Signals Intent to Move from Single-Use Cups and Plastics to Reusable Packaging," press release, January 21, 2020, https://www.asyousow.org/press-releases/starbucks-sustainability-goals-plastic-waste.

108. As You Sow, "As You Sow Statement on McDonald's Recycling Goal Announcement," press release, January 16, 2018, https://www.asyousow.org/press-releases/2018/2/9/as-you-sow-statement-on-mcdonalds-recycling-goal-announcement.

109. As You Sow, "As You Sow Praises Unilever's Plastic Reduction Plan, but Collection Goals Need Unprecedented Collaboration and Funding," press release, October 7, 2019, https://www.asyousow.org/press-releases/2019/10/7/unilever-plastic-recycling-goals.

110. Procter & Gamble, "Reducing Virgin Plastic: P&G's Commitment to Sustainability," n.d., https://www.pggoodeveryday.com/good-news/how-pg-is-reducing-plastic-in-packaging/.

111. As You Sow, "McDonald's Promises to Eliminate Foam Packaging by 2019 in Response to As You Sow Challenge," press release, January 10, 2018, https://www.asyousow.org/press-releases/2018/2/9/mcdonaldss-promises-to-eliminate-foam-packaging-by-2019-in-response-to-as-you-sow-challenge-1.

112. As You Sow, "YUM! Brands Agrees to Phase Out Polystyrene Foam Packaging by 2022 Following Engagement with As You Sow," press release, February 27, 2020, https://www.asyousow.org/press-releases/yum-brands-phase-out-polystyrene-styrofoam-packaging.

113. As You Sow, "Mondelez International Is Fifth Major Company to Agree to As You Sow's Request to Make All Packaging Recyclable," press release, October 10, 2018, https://www.asyousow.org/press-releases/mondelez-international-recycle-packaging.

114. Anne Marie Mohan, "Burger King and Tim Hortons to Pilot Reusable Packaging," Packaging World, January 5, 2021, https://www.packworld.com/issues/sustainability/article/21207262/loop-expands-into-qsr-with-burger-king-and-tim-hortons.

115. Carbon Tracker Initiative, *The Future's Not in Plastics*, https://carbontracker.org/reports/the-futures-not-in-plastics/.

116. Duke Nicholas Institute for Environmental Policy Solutions, "Plastics Policy Inventory," n.d., https://nicholasinstitute.duke.edu/plastics-policy-inventory.

use of plastics by 2030.[117] China, which has been forecast as the market of largest plastic demand growth potential, is set to ban and restrict single-use and disposable plastics over the next five years.[118,119] Europe is on a similar trajectory, with plans for the EU to soon release the latest update of its single-use plastics directive, which seeks to ban certain single-use products, set recycled content targets, and issue a plastic production levy.[120,121] Canada recently announced a ban on single-use plastics that is to go into effect in 2021.[122]

The U.S. is also starting to see policy movement on plastics and passed the Save Our Seas Act 2.0 in late 2020.[123] While the bill focuses on downstream solutions, it leaves upstream accountability unaddressed. The federal Break Free from Plastic Pollution Act, which was introduced in 2020 and re-introduced in 2021, seeks to ban certain single-use plastics, promote Extended Producer Responsibility policies to finance enhanced collection and recycling, and put a temporary pause on new plastic production facilities.[124] Furthermore, a new administration with a focus on climate and environmental justice greatly increases the chances of further action to address and reduce plastic production.[125,126] Local action to regulate plastics is also occurring in the U.S., with nearly 300 municipalities enacting bans or charges on various plastic items.[127] In short, regulatory pushback against plastics is gaining momentum at all levels in the U.S. following stronger pressure demonstrated in the European Union.

Regulations to address plastic waste management are also gaining steam.[128] One notable example is China's "National Sword" policy, which upended global recycling markets by banning the import of most plastic waste it used to accept.[129] More recently, the plastic amendment to the Basel Convention was ratified, classifying plastics as hazardous waste.[130] Together, these policies serve as signposts for investors that the world is rapidly mobilizing against the historical plastic production model.

117. Victoria Masterson, "As Canada Bans Bags and More, This Is What's Happening with Single-Use Plastics around the World," World Economic Forum, October 26, 2020, https://www.weforum.org/agenda/2020/10/canada-bans-single-use-plastics/.

118. Yvonne Shi, "China to Ban, Restrict Production, Sale and Use of Disposable Plastic Products," Independent Commodity Intelligence Services, January 20, 2020, https://www.icis.com/explore/resources/news/2020/01/20/10460342/china-to-ban-restrict-production-sale-and-use-of-disposable-plastic-products.

119. Stephanie Yang, "The Last Straw? China Tries to Trash Single-Use Plastic," *The Wall Street Journal*, January 20, 2020, https://www.wsj.com/articles/china-tries-to-stem-the-flow-of-its-plastic-waste-11579529905.

120. Zero Waste Europe, *Unfolding the Single-Use Plastics Directive*," policy briefing, 2019, https://rethinkplasticalliance.eu/wp-content/uploads/2019/05/ZWE_Unfolding-the-SUP-directive.pdf.

121. Carbon Tracker Initiative, *The Future's Not in Plastics*, https://carbontracker.org/reports/the-futures-not-in-plastics/, 32-33.

122. Government of Canada, "Canada One-Step Closer to Zero Plastic Waste by 2030," press release, October 7, 2020, https://www.canada.ca/en/environment-climate-change/news/2020/10/canada-one-step-closer-to-zero-plastic-waste-by-2030.html.

123. Katie Pyzyk, "Trump Signs Save Our Seas 2.0, Giving Plastics Recycling Infrastructure Potential Boost," WasteDive, December 18, 2020, https://www.wastedive.com/news/congress-save-our-seas-plastic-swana-acc-beyond-plastics/591678/.

124. Stefanie Valentic, "EPR Debate Heats Up as Break Free from Plastic Pollution Act Enters Congress," *Waste* 360, March 29, 2021, https://www.waste360.com/legislation-regulation/epr-debate-heats-break-free-plastic-pollution-act-enters-congress.

125. Center for Biological Diversity, "#PlasticFreePresident: Priority Plastic Actions for President Biden's First Year," n.d., https://plasticfreepresident.org/.

126. Steve Toloken, "Biden EPA Pick Pledges 'Close Look' at Plastics," *Plastics News*, February 4, 2021, https://www.plasticsnews.com/news/biden-epa-pick-pledges-close-look-plastics.

127. Christopher Mims, "Help, We're Drowning in Recycling! Cue the 'Internet of Trash': Tech Won't Solve Our Garbage Problem, but It's at Least a Start," *The Wall Street Journal*, March 2, 2019, https://www.wsj.com/articles/help-were-drowning-in-recycling-cue-the-internet-of-trash-11551502870.

128. Environmental Investigation Agency, *Convention on Plastic Pollution: Towards a New Global Agreement to Address Plastic Pollution*, June 2020, https://www.ciel.org/wp-content/uploads/2020/06/Convention-on-Plastic-Pollution-June-2020-Single-Pages.pdf.

129. Kimiko de Freytas-Tamura, "Plastics Pile up as China Refuses to Take the West's Recycling," *The New York Times*, January 11, 2018, https://www.nytimes.com/2018/01/11/world/china-recyclables-ban.html.

130. David Azoulay and Nathaniel Eisen, *Legal Analysis of the Consequences of the OECD Non-Consensus Determination on the Basel Plastic Amendment*, February 2021, https://www.ciel.org/wp-content/uploads/2021/02/OECD_Basel_Legal-Analysis_FINAL.pdf.

INDUSTRY RESPONSE: PROGRESS OR GREENWASH?

As the transition to a circular economy is beginning to materialize across the world, it is increasingly important for investors to assess the potential for greenwashing and false solutions. This is not a new phenomenon. For instance, oil and gas companies have used public relations campaigns to downplay the impacts of the industry's activities on climate change.[131] Similar campaigns may be occurring around plastics as the industry pushes for the public and investors to perceive only the benefits of plastic production and not its problems. For example, industry campaigns have created and promoted the now well-recognized "chasing arrows" symbol, which has had the unfortunate result of misleading the public regarding the extent to which common plastic products might be recycled; in fact, under 10% of plastics are annually recycled in the U.S.[132,133]

Industry contends that solutions for the world's plastic problem lie in the efficient collection and processing of plastic products at the end of their life, which places responsibility and great costs on consumers, governments, or others at the end of the supply chain, rather than on the producers of plastics (producer responsibility). Recycling certainly plays a role in reducing plastic pollution, but decades of poor performance, even in countries like the U.S. with mature recycling systems, confirm that recycling will not be sufficient to stem the tide of plastic pollution. Further, many oil and gas companies point to membership in industry-sponsored, plastic-related programs like the Alliance to End Plastic Waste (AEPW), support for mechanical recycling, or research into "advanced" recycling to claim they are responsibly contributing to solving the plastic problem.

While these actions may produce certain benefits, recent research has shown that the pace of virgin plastic production is growing faster than the collective commitments toward a circular economy for plastics.[134] Many questions remain unanswered as to whether such voluntary industry programs are or will ever occur at the pace, scale, and scope required to substantially mitigate fundamental issues with plastic use and waste disposal. For example, the AEPW has not publicly announced how much money it has raised and spent on its projects or the progress it has made on achieving its goals. Furthermore, Renew Oceans, a flagship project of the AEPW, is no longer in operation.[135]

Circularity claims by plastic producers have a positive message – pointing to recycling efforts – while such efforts are negated by core industry practices. Awareness is rising that industry's core priority is to continue the extraction of fossil fuels and increase the production of fossil-derived plastics – production that would be reduced if industry's proposed solutions were to fulfill their supposed purpose.[136] This fundamental contradiction must be considered when assessing the likelihood that industry programs will serve their stated purposes.

Two circular innovation areas that investors should approach with caution and an eye toward greenwashing are bioplastics and "advanced" recycling (also referred to as chemical recycling). Although both areas will undoubtedly play a role in the transition to a circular plastic economy, such technologies come with significant limitations and concerns regarding the extent to which they can be considered truly "circular."

131. Andrew R. C. Marshall, Valerie Volcovici, and Sheila Dang, "Climate Change Turns up the Heat on Ad Industry," *Reuters*, December 17, 2020, https://www.reuters.com/article/climate-change-advertising-insight-idUSKBN28R1NJ.

132. Laura Sullivan, "How Big Oil Misled the Public into Believing Plastic Would Be Recycled," *NPR: Morning Edition*, September 11, 2020, https://www.npr.org/2020/09/11/897692090/how-big-oil-misled-the-public-into-believing-plastic-would-be-recycled.

133. U. S. Environmental Protection Agency, "Plastics: Material-Specific Data," n.d., https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data.

134. Stephanie B. Borrelle, Jeremy Ringma, Kara Lavender Law, et al., "Predicted Growth in Plastic Waste Exceeds Efforts to Mitigate Plastic Pollution," *Science* 369, no. 6510 (September 2020), https://doi.org/10.1126/science.aba3656.

135. Joe Brock, John Geddie, and Saurabh Sharma, "Big Oil's Flagship Plastic Waste Project Sinks on the Ganges," *Reuters*, January 17, 2021, https://www.reuters.com/article/environment-plastic/big-oils-flagship-plastic-waste-project-sinks-on-the-ganges-idUSKBN29N028.

136. Tabuchi et al., "Big Oil Is in Trouble," https://www.nytimes.com/2020/08/30/climate/oil-kenya-africa-plastics-trade.html.

Bio-Based Plastics and Other Bioplastics

Bioplastics are predicted to grow in market share and production capacity to nearly $27.9 billion and 2.8 million tonnes by 2025, respectively (from $10.5 billion and 2.1 million tonnes in 2020),[137] but questions remain about their benefits and limitations. In their most circular form, bioplastics are derived from natural sources and biodegrade at the end of their life, both reducing the lifecycle emissions of the produced resin and decoupling plastic production from fossil fuel extraction.[138] The main bioplastics that currently fit these criteria are derived from starches and other organic material (e.g., PLA cups and utensils).[139] However, these bioplastics currently make up less than 1% of global polymer production and have lower projected annual growth rates than their commodity fossil-derived counterparts (PE, PP, PET).[140] Furthermore, access to appropriate end-of-life infrastructure remains a huge challenge, with less than 2% of the U.S. population having access to industrial composting (and even less in developing countries).[141]

Without significant intervention (e.g., a plastic tax, bioplastic subsidy, willingness to pay bioplastic price premium, etc.), bioplastics will continue to struggle to be competitive with fossil-derived plastics, raising concerns that they are more of a “distraction” than a solution.[142,143] Additionally, a high level of scrutiny is still needed to evaluate the true circularity of these bioplastics – land-use change emissions, competition with other agricultural resources, environmental impact assessment, and feasibility of industrial composting all remain in question.[144,145] In order to fully address these questions, further research and development are needed.

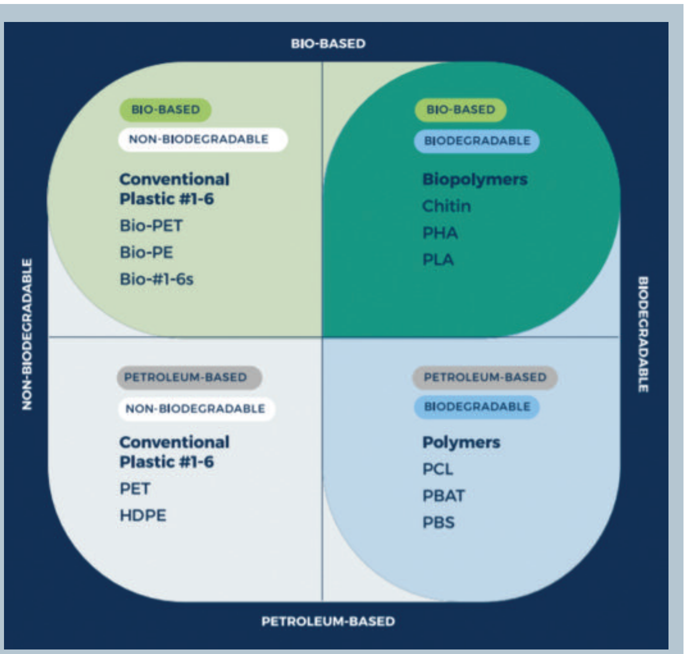

Figure 4: Interrelationship Between Conventional, Bio-Based, and Biodegradable Plastics

SOURCE: Closed Loop Partners, *Navigating Plastic Alternatives in a Circular Economy: A Closed Loop Partners Report*, 2020, https://www.closedlooppartners.com/wp-content/uploads/2020/12/Navigating-Plastic-Alternatives-In-a-Circular-Economy.pdf.

There are no set standards for what qualifies as a bioplastic (see Figure 4). Some bioplastics are not biodegradable (e.g., BioPE and BioPET). These “bio-based plastics” or “drop-in bioplastics” are chemically identical to their fossil-derived counterparts but differ in the raw feedstock used to produce the final polymer.[146] Chemical companies like BASF offer a portfolio of bio-based

137. Hannah Friedman, *Navigating Plastic Alternatives in a Circular Economy: A Closed Loop Partners Report*, n.d., https://www.closedlooppartners.com/wp-content/uploads/2020/12/Navigating-Plastic-Alternatives-In-a-Circular-Economy.pdf.
138. Renzo Pipoli, “Bioplastics Struggle to Build Scale and Grow into Bigger Alternative to Petrochemicals,” Reuters Events, Downstream, December 13, 2020, https://www.reutersevents.com/downstream/process-safety-ehs/bioplastics-struggle-build-scale-and-grow-bigger-alternative-petrochemicals/.
139. Guy Bailey and Ashish Chitalia, “Can Bioplastics Make the Chemicals Industry Greener?” Wood Mackenzie, October 15, 2020, https://www.woodmac.com/news/opinion/can-bioplastics-make-the-chemicals-industry-greener/.
140. Ibid.
141. Virginia Streeter and Brenda Platt, “Residential Food Waste Collection Access in the U.S.,” *BioCycle*, December 6, 2017, https://www.biocycle.net/2017/12/06/residential-food-waste-collection-access-u-s/.
142. Bailey and Chitalia, “Can Bioplastics,” https://www.woodmac.com/news/opinion/can-bioplastics-make-the-chemicals-industry-greener/.
143. Pipoli, “Bioplastics Struggle,” https://www.reutersevents.com/downstream/process-safety-ehs/bioplastics-struggle-build-scale-and-grow-bigger-alternative-petrochemicals/.
144. Ibid.
145. Bailey and Chitalia, “Can Bioplastics,” https://www.woodmac.com/news/opinion/can-bioplastics-make-the-chemicals-industry-greener/.
146. Plastics Europe, “Bio-Based Plastics,” n.d., https://www.plasticseurope.org/en/about-plastics/what-are-plastics/large-family/bio-based-plastics.

products to “reduce the carbon footprint” of what are usually fossil-derived plastics.[147] While a reduction in lifecycle emissions is a positive attribute of these products, bio-based plastics face the same end-of-life treatment as their fossil-derived counterparts and do not “turn off the tap” of plastic production or the flow of mismanaged plastic waste into the oceans or environment.

The inability to distinguish between polymers that are bio-based or fossil-based presents an opportunity for companies to make circularity claims about products when only a portion comes from renewable feedstocks. This is seen in the “biomass balance” approach championed by BASF[148] and lauded by groups like PlasticsEurope.[149] BASF’s biomass balance approach allows customers to pay for a certain amount of renewable feedstock to be used in the production of the company’s chemical products. While BASF cannot guarantee how much of a product is renewably sourced, it will certify the customer-purchased “fossil savings.”[150] The push to advance alternative, renewable feedstocks in the petrochemical sector is a positive step, but it does not address the need to reduce virgin plastic production in absolute numbers – an essential part of transitioning to a circular plastic economy.

Mechanical and Chemical Recycling

Recycling is the “process of collecting and processing materials that would otherwise be thrown away as trash and turning them into new products.”[151] Mechanical recycling has existed at an industrial scale since the 1980s.[152] Today, mechanical recycling is the incumbent technology and has well-studied economic and environmental benefits. However, it is both underutilized and underfunded, leading to abysmal recycling rates in the U.S. and globally.[153] A recent report by The Recycling Partnership found that the current, broken U.S. curbside recycling system needs an estimated $12 billion of new investment to perform properly, of which only 7% ($870 million) has been raised.[154]

In response to mounting opposition to plastic pollution and increasing research highlighting the state of the broken recycling system, chemical or “advanced” recycling has been pushed by industry groups like the ACC and Chemical Recycling Europe as industry’s silver bullet.[155,156] The growing hype around chemical recycling stems from its potential to overcome limitations of mechanical recycling (mainly quality degradation). At its most promising, chemical recycling presents the possibility of “infinite recyclability” and upcycling of low-quality, hard-to-recycle plastic waste into virgin-quality plastics and other valuable chemicals. The promise of chemical recycling is

147. BASF, “Product Examples,” 2021, https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy/dedicated-bio-based-production.html.
148. BASF, “BASF’s Biomass Balance Approach,” 2021, https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy/mass-balance-approach/biomass-balance/biomass-balance.html.
149. Plastics Europe, “Bio-Based Plastics,” https://www.plasticseurope.org/en/about-plastics/what-are-plastics/large-family/bio-based-plastics.
150. BASF, “BASF’s Biomass Balance,” https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy/mass-balance-approach/biomass-balance/biomass-balance.html.
151. U.S. Environmental Protection Agency, “Recycling Basics,” n.d., https://www.epa.gov/recycle/recycling-basics#Steps.
152. Geyer et al., “Production, Use, and Fate,” https://doi.org/10.1126/sciadv.1700782.
153. Maurizio Crippa, Bruno De Wilde, Rudy Koopmans, et al., *A Circular Economy for Plastics: Insights from Research and Innovation to Inform Policy and Funding Decisions*, European Commission, January 2019, https://www.hbm4eu.eu/wp-content/uploads/2019/03/2019_RI_Report_A-circular-economy-for-plastics.pdf.
154. Scott Mouw, *2020 State of Curbside Recycling Report*, The Recycling Partnership, February 13, 2020, https://recyclingpartnership.org/stateofcurbside/.
155. American Chemistry Council, “Advanced Recycling Alliance for Plastics (ARAP),” 2021, https://plastics.americanchemistry.com/Advanced-Recycling-Alliance-for-Plastics.html.
156. Chemical Recycling Europe, 2019, https://www.chemicalrecyclingeurope.eu/.

undeniably attractive, and it will certainly play a role in the transition to a circular economy. However, there are a variety of issues that should deeply concern investors about chemical recycling technologies – mainly, their unproven economic and environmental performance at scale as well as the high potential for inaccurate greenwashing of "plastic-to-fuel" linear pathways as "circular."

Chemical recycling includes a wide array of technologies, all of which are in early stages of development.[157] These include "conversion" processes like pyrolysis and gasification that convert plastic waste into other hydrocarbon products, "depolymerization" processes that break plastic polymers into base monomers, and "purification" processes that dissolve plastic polymers into a solvent solution to be purified and precipitated by an anti-solvent.[158,159]

Of particular concern to investors are pyrolysis and gasification, which are currently the main chemical recycling pathways for polyolefins – PE and PP – which account for two-thirds of the global plastic economy.[160] These technologies have historically been developed and used for plastic-to-fuel markets, which are not considered circular and therefore do not reduce the need for continued virgin plastic production.[161,162] Plastic-to-plastic pyrolysis pathways are theoretically possible and have been touted recently by companies like CPChem,[163] BASF,[164] and Shell.[165] However, it is widely recognized that only a fraction, if any, of pyrolysis products are suitable to produce new plastics, while most would be used in cheaper plastic-to-fuel pathways. Plastic gasification faces similar hurdles.[166,167]

Breaking the Plastic Wave states that the vast majority of the current global "advanced" recycling capacity (1.4 million tonnes per year) is for plastic-to-fuel.[168] A recent report by GAIA found that of the 37 chemical recycling facilities proposed since 2000, only three are operational and none has successfully produced new plastic.[169] This has led to prominent agencies such as the European Commission to view "advanced" recycling as only a last resort solution for plastic waste.[170] Despite this, the ACC continues to push for U.S. state legislation to promote plastic-to-fuel pathways as a solution.[171,172] Industry must reckon with how it will prioritize plastic-to-plastic outcomes to demonstrate a genuine commitment to circularity.

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157. The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave*, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.
158. Closed Loop Partners, *A Landscape Mapping of the Advanced Plastics Recycling Market*, 2020, https://www.closedlooppartners.com/research/advancing-circular-systems-for-plastics/.
159. James Sherwood, "Closed-Loop Recycling of Polymers Using Solvents: Remaking Plastics for a Circular Economy," *Johnson Matthew Technology Review* 64, no. 1 (2020): 4-15, https://doi.org/10.1595/205651319X15574756736831.
160. Joshua C. Worch and Andrew P. Dove, "100th Anniversary of Macromolecular Science Viewpoint: Toward Catalytic Chemical Recycling of Waste (and Future) Plastics," *ACS Macro Letters* 9, no. 11 (2020): 1494-1506, https://doi.org/10.1021/acsmacrolett.0c00582.
161. Ibid.
162. Martyna Solis and Semida Silveira, "Technologies for Chemical Recycling of Household Plastics – A Technical Review and TRL Assessment," *Waste Management* 105 (March 2020): 128-138, https://doi.org/10.1016/j.wasman.2020.01.038.
163. Chevron Phillips Chemical, *Advanced Recycling*, n.d., https://www.cpchem.com/sites/default/files/2020-12/Advanced%20Recycling.pdf.
164. BASF, "ChemCycling™," 2021, https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy/mass-balance-approach/chemcycling.html.
165. Shell Chemicals, "Nexus and Shell Sign Strategic Supply Agreement to Scale up Commercial Production of Chemicals from Plastic Waste," press release, November 19, 2020, https://www.shell.com/business-customers/chemicals/media-releases/2020-media-releases/nexus-and-shell-sign-strategic-supply-agreement-to-scale-up-commercial-production-of-chemicals-from-plastic-waste.html.
166. Crippa et al., *A Circular Economy*, https://www.hbm4eu.eu/wp-content/uploads/2019/03/2019_RI_Report_A-circular-economy-for-plastics.pdf.
167. Andrew N. Rollinson and Jumoke Oladejo, *Chemical Recycling: Status, Sustainability, and Environmental Impacts*, 2020, https://doi.org/10.46556/ONL4535.
168. The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave*, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.
169. Denise Patel, Doun Moon, Neil Tangri, and Monica Wilson, *All Talk and No Recycling: An Investigation of the U.S. "Chemical Recycling" Industry*, 2020, https://www.no-burn.org/wp-content/uploads/All-Talk-and-No-Recycling_July-28.pdf.
170. Kira Taylor, "Chemical Recycling Should Be Seen as a Last Resort, EU Official Says," *Euractiv*, December 8, 2020, https://www.euractiv.com/section/energy-environment/news/chemical-recycling-should-be-seen-as-a-last-resort-eu-official-says/.
171. GAIA, *State Legislation Alert*, July 28, 2020, https://www.no-burn.org/wp-content/uploads/US-ACC-State-Legislation-Alert_updated-July-2020.pdf.
172. American Chemistry Council, *Regulatory Treatment of Manufacturing Facilities that Convert Post-Use Plastics to Fuels, Chemical Feedstocks and Other Petroleum Products*, 2018, https://plastics.americanchemistry.com/Product-Groups-and-Stats/Plastics-to-Fuel/Regulatory-Treatment-of-Plastics-to-Fuel-Facilities.pdf.

Table 1: "Advanced" Recycling Technologies Comparison

Technology Group	Applicable Commodity Plastics (PE, PP, PET, PS, PVC)*	Main Benefits	Main Concerns
Pyrolysis *Conversion of plastic waste into a desired liquid product ("pyrolysis oil").*	PE PP PS	• Can handle mixed plastic waste and higher levels of contamination than mechanical recycling • Potential for plastic-to-plastic recycling • Flexible technology (many process variables to tune) • Products can be processed in existing refinery equipment	• Plastic-to-fuel more likely • Large feedstock and energy requirement • Cost of collection, sorting, and pre-treatment at scale • Low-quality products • Lack of economic and environmental data at scale
Gasification *Conversion of plastic waste into a desired gas product (usually syngas).*	PE PP PS	• Can handle mixed plastic waste and higher levels of contamination than mechanical recycling • Potential for plastic-to-plastic recycling • Syngas is a valuable product • Products can be processed in existing refinery equipment	• Plastic-to-fuel or plastic-to-fertilizer more likely • Large feedstock and energy requirement • Cost of collection, sorting, and pre-treatment at scale • Large environmental concerns
Purification *Purification of plastic polymers with the use of solvents.*	PET PVC PS PE PP	• Potential for near-virgin recycling of several key polymers and removal of additives • Potential as a waste-sorting technology	• Cost of solvent/anti-solvent (if solvent recovery is low) • Large, single-stream feedstock requirement • Concerns about quality of products
Depolymerization *Chemical degradation of plastic polymers into base monomers with the use of solvents.*	PET	• Potential for "infinite recyclability" into virgin-grade plastic	• Most undeveloped and unproven chemical recycling technology • Cost of solvent (if solvent recovery is low) • Large, single-stream feedstock requirement • Concerns about quality of products

* Analysis of chemical recycling technologies considered only main commodity plastics (resin codes #1-6)

Table 1 summarizes relevant features, benefits, and limitations of the four main chemical recycling technology groups at a high level, acknowledging there may be technology-specific exceptions to descriptions as stated. Although each group has its specific benefits and weaknesses, all lack economic and environmental data needed for comprehensive evaluation. Even pyrolysis, the most mature and studied technology, has no existing semi-industrial operations.[173] The main economic concern for all technologies is a large feedstock requirement and the associated costs of collection, sorting, and pre-treatment necessary for industrial operation.[174] Pyrolysis and gasification come with additional large costs from high energy requirements (> 500°C, often with a catalyst) and

173. Peter Quicker, *Evaluation of Recent Developments Regarding Alternative Thermal Waste Treatment with a Focus on Depolymerisation Processes*, 2019, https://www.vivis.de/wp-content/uploads/WM9/2019_WM_359-370_Quicker.pdf.

174. Zero Waste Europe, *El Dorado of Chemical Recycling: State of Play and Policy Changes*, August 2019, https://zerowasteeurope.eu/downloads/el-dorado-of-chemical-recycling-state-of-play-and-policy-challenges/.

require additional upgrading or "clean-up" for plastic-to-plastic pathways.[175,176] Purification and depolymerization have large costs associated with the use of expensive solvents (if solvent recovery rates are low) as well as additional energy needed for solvent recovery.[177] Pyrolysis and gasification spark significant environmental concerns, including the potential for emissions of heavy metals, dioxins, nitrogen oxides (NOx), sulfur oxides (SOx), and volatile organic compounds (VOCs) that have adverse environmental and human health effects.[178,179] Although a variety of industry-sponsored life cycle assessments (LCAs) have been published on pyrolysis processes, the studies have faced significant criticism for not publicly providing data or important assumptions used, which can heavily affect the results of the LCA.[180]

While each technology group may play a role in the plastic economy, the size of that role remains in question. "Advanced" recycling technologies, on average, take 17 years to reach growth scale.[181] When compared to solutions focused on reducing production and demand of plastic materials, chemical recycling falls short of its hype. This is demonstrated in the *Breaking the Plastic Wave*'s conclusion that the growth of plastic-to-plastic chemical recycling *at scale* is only likely to begin after 2030 and can only tackle 6% of plastic waste by 2040.[182] Further research is needed to resolve such serious questions regarding company claims about chemical recycling's promised impact. Existing, additional resources on "advanced" recycling can be found in Appendix A.

KEY BENCHMARKS AND BEST PRACTICES ASSOCIATED WITH PLASTIC POLLUTION

Consideration of Plastic Demand Impacts from the Global Response to Plastic Pollution

Benchmark Questions:

- Does the company disclose specific information about the type of petrochemical products being produced (aromatics, packaging plastics, performance chemicals, etc.)?
- Is the company disclosing for what end use it expects its products to be used (e. g., for single-use plastics, durable plastics, etc.)?
- Does the company disclose its assumptions on plastic demand growth, and specifically what type of plastic (single-use)?
- Does the company assess how the public, market, and governmental responses to the plastic problem might reduce demand growth assumptions for plastic? If so, does it discuss how that reduced demand would impact the company's petrochemical investments?
- Does the company assess scenarios of increased plastic regulation in its long-term planning (e.g., a global ban on single-use plastics)?

175. Ibid.
176. Crippa et al., *A Circular Economy*, https://www.hbm4eu.eu/wp-content/uploads/2019/03/2019_RI_Report_A-circular-economy-for-plastics.pdf.
177. Sherwood, "Closed-Loop Recycling," https://doi.org/10.1595/205651319X15574756736831.
178. Rollinson and Oladejo, *Chemical Recycling*, https://doi.org/10.46556/ONL4535.
179. The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave*, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.
180. Zero Waste Europe, *Understanding the Environmental Impacts of Chemical Recycling: Ten Concerns with Existing Life Cycle Assessments*, December 2020, https://zerowasteeurope.eu/wp-content/uploads/2020/12/zwe_jointpaper_UnderstandingEnvironmentalImpactsofCR_en.pdf.
181. Closed Loop Partners, *A Landscape Mapping*, https://www.closedlooppartners.com/research/advancing-circular-systems-for-plastics/.
182. The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave*, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.

Best Practice Example: BP included a global single-use plastics ban scenario in its 2019 *Energy Outlook*.[183] BP continues to forecast oil demand for plastic resins and fibers under different transition scenarios in addition to business-as-usual and discusses how its forecasts have shifted from previous predictions.[184]

Circular Technology Commitments

Benchmark Questions:

- How much is the company investing in solutions like bioplastics, mechanical recycling, or "advanced" recycling?
- What impact does the company expect such investments to have, and how would those impacts reduce demand for the company's core products? (What percentage of the company's total production does chemically recycled plastic make up or does the company expect it to make up?)
- Does the company transparently discuss the benefits and trade-offs of the "advanced" recycling pathways in which it is investing (energy use, environmental impact, cost, carbon emissions, water use, final product yield, etc.)?
- If the company has invested in an "advanced" recycling venture, does that venture transparently disclose its facility-level impacts (emissions and waste generation), the solvents used in its chemical processes and their fate, and adherence to local regulations?
- Is the company investing significantly in reducing technical roadblocks to plastic-to-plastic recycling and minimizing less circular pathways like plastic-to-fuel and plastic-to-fertilizer?

Best Practice Example: CPChem and Exxon have both recently announced partnerships with pyrolysis companies to produce plastics from waste plastic-derived feedstocks. CPChem announced its intent to produce 1 billion pounds (500,000 tons) of pyrolysis-derived PE annually by 2030 while Exxon's new JV, Cyclyx International, aims to process 3 million tons of plastic waste annually by 2030.[185,186] While these projects are positive steps, disclosure remains lacking on the details of these projects and how they relate to broader company actions. For example, while CPChem's circular PE line demonstrates the potential for plastic-to-plastic pyrolysis, it is unclear how such recycling would decrease its fossil-based plastic production, if at all, by 2030. Also, Exxon's JV has not clarified if it will focus on plastic-to-plastic pyrolysis or the cheaper plastic-to-fuel pathway. Investors need further transparency on the environmental and economic performance of each.

Plastic Policy Engagement

Benchmark Questions:

- Does the company oppose measures intended to mitigate the plastic pollution problem (i.e., foam, bag, or straw bans or fees)?
- Does the company spend money on lobbying against plastic reduction measures at the local or national level?
- Does the company block local or national policies targeting upstream solutions like reuse, refill, and elimination?

183. BP Energy Economics, *BP Energy Outlook: 2019 Edition*, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2019.pdf, 35.
184. Ibid, 39.
185. Chevron Phillips Chemical, "Marlex® Anew™ Circular Polyethylene: Leading Circular Plastics," n.d., https://www.cpchem.com/AdvancedRecycling.
186. Al Greenwood, "Agilyx, ExxonMobil Form Cyclix Plastic-Recycling JV," press release, December 11, 2020, https://www.icis.com/explore/resources/news/2020/12/11/10585303/agilyx-exxonmobil-form-cyclyx-plastic-recycling-jv.

– Does the company disclose instances where it is misaligned with a trade association's opposition to plastic regulation?

– Does the company support Extended Producer Responsibility schemes and other efforts to address plastics systemically?

Best Practice Example: Investors in the Climate Action 100+ initiative have provided guidance on investor expectations for alignment of lobbying activities (direct and indirect) with climate goals.[187] Ceres provided additional resources in a report on responsible policy engagement on climate change.[188] Such expectations can also be applied for alignment with other plastic-related environmental and social goals.

PETROCHEMICALS AND THE CLIMATE CRISIS

If plastic production grows as a major driver of oil demand in the coming decades under a business-as-usual scenario, investors must understand the climate implications of that growth. Where does plastic fit into the climate crisis?

INDUSTRY NARRATIVE AND THE COMPLEXITIES OF LIFECYCLE ANALYSES

Industry's narrative is that plastic products are essential to quality of life and generate fewer GHG emissions than common alternatives. Companies like ExxonMobil,[189] Dow Inc.,[190] and CPChem[191] express this claim in recent sustainability reports while forecasting plastics as an area of significant growth for their businesses. Even Shell, which has made significant shifts in its operations relative to its U.S. peers, cites a growth in chemicals as part of its "low-carbon strategy."[192]

To defend such viewpoints, companies point to industry-sponsored life cycle assessments that draw narrow conclusions about the environmental benefits of certain plastic products over certain alternatives in specific circumstances.[193] These narrow conclusions are often inaccurately presented to support the benefits of plastics and to suggest that environmental damage could occur from completely replacing plastic products, which is an

187. Ceres, *Investor Expectations on Corporate Lobbying in Climate Change*, n.d., https://www.ceres.org/sites/default/files/INVESTOR%20EXPECTATIONS%20ON%20CORPORATE%20LOBBYING%20ON%20CLIMATE%20CHANGE%209.19.pdf.

188. Ceres, *Blueprint for Responsible Policy Engagement on Climate Change*, July 16, 2020, https://www.ceres.org/resources/reports/blueprint-responsible-policy-engagement-climate-change.

189. ExxonMobil, *Sustainability Report Highlights*, January 2021, https://corporate.exxonmobil.com/-/media/Global/Files/sustainability-report/publication/Sustainability-Report.pdf, 13.

190. Dow, *Sustainability Report 2019*, 2020, https://nshosting.dow.com/sustainability2019/includes/downloads/Sustainability_Report_2019.pdf, 8.

191. Chevron Phillips Chemical, *Embracing Progress: 2019 Sustainability Report*, 2020, https://www.cpchem.com/2019Report/assets/downloads/Embracing_Progress_CPCHEM_2019_sustainability_report.pdf, 11.

192. Will Beacham, "Shell Commits to Growing Chemicals as Part of Low-Carbon Strategy," February 11, 2021, https://www.icis.com/explore/resources/news/2021/02/11/10605847/shell-commits-to-growing-chemicals-as-part-of-low-carbon-strategy.

193. Franklin Associates, *Impact of Plastics Packaging on Life Cycle Energy Consumption & Greenhouse Gas Emissions in the United States and Canada: Substitution Analysis*, American Chemistry Council and Canadian Plastics Industry Association, January 2014, https://plastics.americanchemistry.com/Education-Resources/Publications/Impact-of-Plastics-Packaging.pdf.

unrealistic scenario.[194,195] Some plastic products serve essential functions (such as those used in healthcare), but others can and should be feasibly eliminated or replaced[196] – industry-provided LCAs do not address this nuance. Furthermore, while it is possible for substitute materials to have a larger climate footprint than their plastic counterparts on a single-use basis, significant GHG emissions savings can be achieved when substitute materials are used with high reuse or recycling rates.[197]

While further research is needed to provide independent, comprehensive LCAs of plastics and their substitutes, industry's misleading use of such complex studies leads to the troubling conclusion that an increase in plastic production, and all its associated emissions, is somehow in line with the Paris Agreement; in fact, as discussed below, the opposite is true.

PLASTICS' CONTRIBUTION TO CLIMATE CHANGE

Plastic Lifecycle Emissions

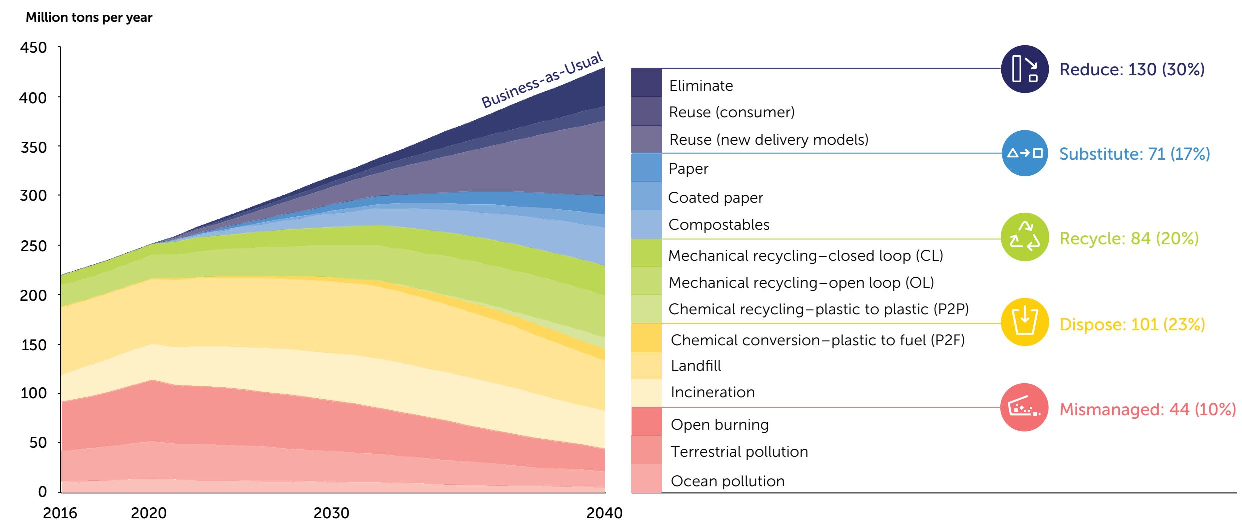
Plastic supply chains overall (from feedstock extraction to disposal) have a considerable carbon footprint.[198] Using data from the Environmental Protection Agency's (EPA) GHG Reporting Program, the Environmental Integrity Project (EIP) found that the chemical sector rose in reported GHG emissions by 9.1 million tons between 2016 and 2019, mainly due to increased production from the petrochemicals and plastics subsector. Furthermore, this subsector is projected to account for more than three quarters of the chemical sector's potential GHG emissions increase by 2026.[199] Using data from *Breaking the Plastic Wave*, Carbon Tracker concludes that the current emissions rate for plastic is on average just over 5 tonnes of CO_2 per tonne of plastic, roughly double that of oil in 2019 (2.6 tonnes of CO_2 per tonne of oil).[200] Unabated, these emissions could grow to consume up to 19% of the remaining carbon budget to limit global mean temperature rise to below 1.5°C.[201,202] Other peer-reviewed studies similarly found that the global plastic footprint, under business-as-usual growth, would use 15% of the remaining carbon budget.[203] As such, increasing plastic production and its associated emissions runs counter to achieving Paris goals, and claims to the contrary must be viewed with caution.[204]

While it is clear that the plastic supply chain contributes significantly to climate change, calculating the full lifecycle emissions of plastic is a complicated process, made more challenging by a lack of clear and transparent company disclosure on associated emissions. See Appendix B for an in-depth overview of the emissions associated with each plastic lifecycle stage.

194. *How Plastics Can Help Enhance a Package's Environmental Performance*, infographic, n.d., https://plastics.americanchemistry.com/fact-sheets-and-infographics/how-plastics-can-help-improve-packaging-environmental-performance.pdf.
195. American Chemistry Council, "Study from Trucost Finds Plastics Reduce Environmental Costs by Nearly 4 Times Compared to Alternatives," press release, July 2016, https://plastics.americanchemistry.com/Study-from-Trucost-Finds-Plastics-Reduce-Environmental-Costs/.
196. The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave*, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf, 55-61.
197. Ibid.
198. Lisa Anne Hamilton, Steven Feit, Matt Kelso, Samantha Malone Rubright, Courtney Bernhardt, Eric Schaeffer, Doun Moon, Jeffrey Morris, and Rachel Labbe-Bellas, *Plastic & Climate: The Hidden Costs of a Plastic Planet*, May 2019, https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf.
199. Environmental Integrity Project, *Analysis of 2019 Data on Greenhouse Gasses from Oil, Gas, and Petrochemical Production*, December 17, 2020, https://environmentalintegrity.org/wp-content/uploads/2020/12/Oil-and-Gas-Industry-Greenhouse-Gas-report-12.17.2020.pdf.
200. Carbon Tracker Initiative, *The Future's Not in Plastics*, 9-10, https://carbontracker.org/reports/the-futures-not-in-plastics/.
201. Hamilton et al., *Plastic & Climate*, https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf.
202. The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave*, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.
203. Jiajia Zheng and Sangwon Suh, "Strategies to Reduce the Global Carbon Footprint of Plastics, *Nature Climate Change*, 9 (2019): 374-378, https://www.nature.com/articles/s41558-019-0459-z.
204. Carbon Tracker Initiative, *The Future's Not in Plastics*, 10, https://carbontracker.org/reports/the-futures-not-in-plastics/.

Strategies to Decarbonize the Plastic Industry

The *Breaking the Plastic Wave* report presents an ambitious but feasible and integrated pathway (see Figure 5) to reduce mismanaged plastic waste with 25% less GHG emissions by 2040 compared to business-as-usual. This "System Change" scenario results in a 55% reduction of virgin plastic demand, with most of the reduction coming from elimination and reuse.[205] The emissions savings of this pathway could be expanded if there were a simultaneous push to power the plastic industry, especially its cracking facilities, with renewable energy. Studies have found that low-carbon energy could reduce overall emissions from the plastic industry by half, noting significant feasibility limitations.[206] This remains an area of active research.[207]



This "wedges" figure shows the share of treatment options for the plastic that enters the system over time under the System Change Scenario. Any plastic that enters the system has a single fate, or a single "wedge." The numbers include macroplastic and microplastic.

Figure 5: Plastic Fate Categories under Breaking the Plastic Wave's "System Change Scenario"

SOURCE: Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution*, 2020, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.

Case Study: The Wild West of Petrochemical Emission Disclosure

As investors seek to understand companies' full impact on the climate crisis, better transparency from companies involved in the petrochemical supply chain is urgently needed. Companies within the refining, chemical and petroleum-based product manufacturing, and consumer goods sectors currently disclose emissions in unstandardized, difficult-to-compare ways. Accounting for the full lifecycle impacts of a company's petrochemical operations is critical and needs improvement.

Investors seek accounting for the full range of emissions from companies' petrochemical products (Scopes 1, 2, and 3, as defined by the Global Reporting Initiative (GRI)).[208] This varies from company to company depending on where they sit in the supply chain (see Figure 6) but should include comprehensive Scope 3 (indirect, supply

205. The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave*, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.

206. Hamilton et al., *Plastic & Climate*, https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf, 51-52.

207. Alexander H. Tullo, "The Search for Greener Ethylene: Making the Basic Chemical Produces Substantial Carbon Emissions. Chemical Companies Are Trying to Change That," *Chemical & Engineering News* 99, no. 9 (March 15, 2021), https://cen.acs.org/business/petrochemicals/search-greener-ethylene/99/i9.

208. Global Sustainability Standards Board, *GRI Standards Glossary 2020*, https://www.globalreporting.org/standards/media/2594/gri-standard-glossary-2020.pdf.

chain) emissions disclosure. Dow Inc., for example, discloses both its upstream emissions from purchased plastic feedstocks like ethylene as well as the end-of-life emissions of the plastic resins it produces.[209] In contrast, Exxon, which only recently began disclosing its Scope 3 emissions for fuels, does not measure Scope 3 emissions for other petroleum-based products.[210] Exxon operates significant ethylene production capacity and is responsible for more than one quarter of PE capacity in the Plastic Production Corridor.[211,212] It further announced in 2019 that it had plans to build or expand 11 manufacturing facilities in the Gulf Coast over the next decade, including a JV project with SABIC to build the world's largest ethane cracker.[213] As such, investors are concerned that a significant portion of its emissions will continue to be uncounted.

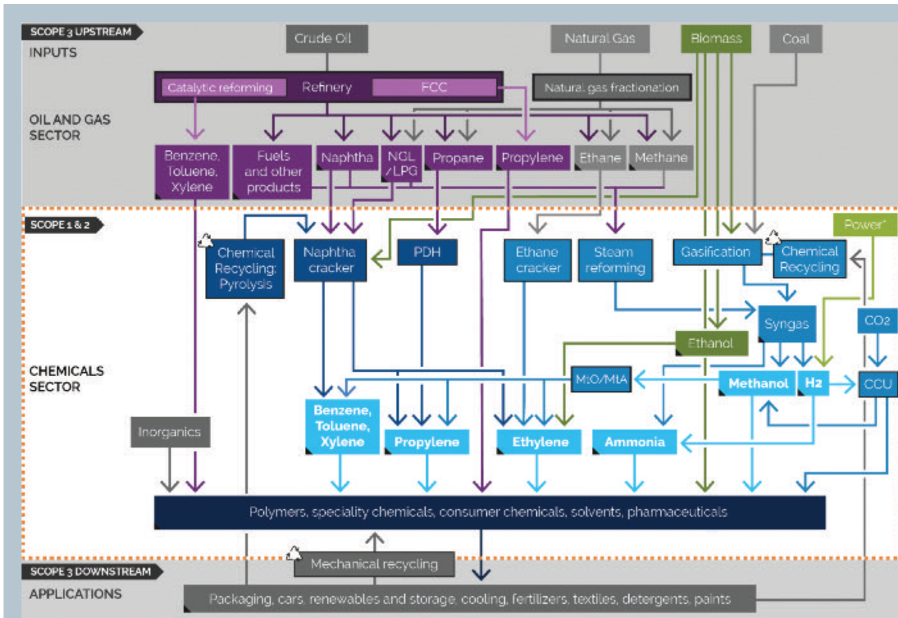


Figure 6: Chemicals Value Chain

SOURCE: Science Based Targets, *Barriers, Challenges, and Opportunities for Chemical Companies to Set Science-Based Targets*, 2020, https://sciencebasedtargets.org/resources/files/SBTi-Chemicals-Scoping-Document-12.2020.pdf.

JV petrochemical projects present another challenge for accounting fully for upstream emissions associated with plastics and other petrochemicals.[214] CPChem, the JV petrochemical company owned by Chevron and Phillips 66, provides an example of how confusing emissions disclosures for JVs can be. Both parent companies mention in their most recent sustainability reports that their disclosed emissions data do not reflect the emissions of CPChem because it publishes its own public reports.[215,216] However, CPChem does not disclose Scope 3 emissions.[217] Phillips 66 also does not disclose Scope 3 emissions (Chevron does).[218] CPChem is the third largest polyolefin producer in the Corridor[219] and has plans to expand, most notably with its own planned JV cracker project with Qatar Petroleum, presenting yet another level of complexity for emissions disclosure.[220]

209. Dow, *Sustainability Report 2019*, https://nshosting.dow.com/sustainability2019/includes/downloads/Sustainability_Report_2019.pdf.

210. Kevin Crowley and Ashkat Rathi, "Exxon Discloses Full Scope of Fuel Emissions for the First Time," *Bloomberg*, January 5, 2021, https://www.bloomberg.com/news/articles/2021-01-05/exxon-reveals-petroleum-product-emissions-data-for-first-time.

211. Data analyzed from Planet Tracker, *Stormy Outlook*, https://planet-tracker.org/tracker-programmes/materials/plastics/#stormy-outlook.

212. Hamilton et al., *Plastic & Climate*, https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf.

213. Renzo Pipoli, "ExxonMobil Cuts 2021 Capital Expenditure but Will Finish Corpus Christi Plants ahead of Schedule," Reuters Events, Downstream, February 9, 2021, https://www.reutersevents.com/downstream/supply-chain-logistics/exxonmobil-cuts-2021-capital-expenditure-will-finish-corpus-christi-plants/.

214. Meredith Block, Dominic Watson, Louise White, and Ben Ratner, *Emission Omission: A Shareholder Engagement Guide to Uncovering Climate Risks from Non-Operated Assets in the Oil and Gas Industry*, October 2020, https://business.edf.org/insights/emission-omission/.

215. Chevron Corporation, *The Human Energy Company: 2019 Corporate Sustainability Report*, 2020, https://www.chevron.com/-/media/shared-media/documents/2019-corporate-sustainability-report.pdf, 45.

216. Phillips 66, *Greater Good: Sustainability at Phillips 66*, 2020, https://phillips66.widen.net/s/kltplqhksf/20-0019-sustainability-report.print, 8.

217. Chevron Phillips Chemical, *Embracing Progress*, https://www.cpchem.com/2019Report/assets/downloads/Embracing_Progress_CPCHEM_2019_sustainability_report.pdf, 47.

218. Ibid.

219. Data analyzed from Planet Tracker, *Stormy Outlook*, https://planet-tracker.org/tracker-programmes/materials/plastics/#stormy-outlook.

220. Joseph Chang, "Chevron Phillips Chemical to Deter FID on Second US Gulf Coast Petrochemicals Project, October 20, 2020, https://www.icis.com/explore/resources/news/2020/10/20/10565246/chevron-philips-chemical-to-defer-fid-on-second-us-gulf-coast-petrochemicals-project.

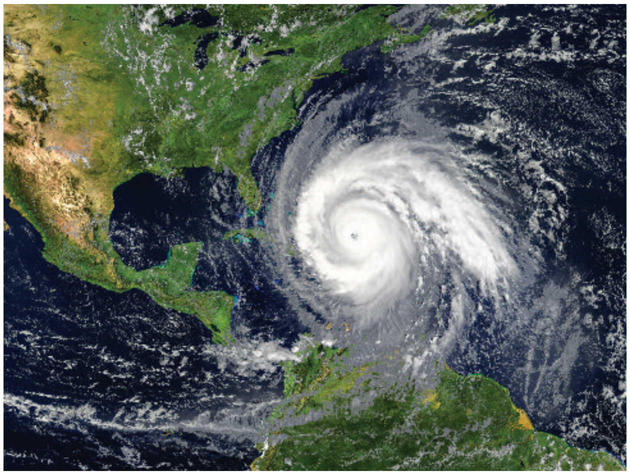
Given the predicted dominance that plastic production will have on oil demand through mid-century, these disclosure issues become material as involved companies set emissions reduction targets or net-zero goals. When assessing these company disclosures and targets, it is critical for investors to understand which activities are “in scope” and which are left unaddressed. Existing frameworks such as the Science Based Targets Initiative (SBTi),[221] GRI,[222] and Sustainability Accounting Standards Board (SASB)[223] have yet to fully grapple with how to account for companies that span the petrochemical and oil and gas sectors and have impacts that reach far beyond the part or parts of the plastic value chain in which they sit. All three are in various stages of setting or updating relevant standards but still demonstrate inconsistences in determining how companies that span the two sectors should account for related emissions (see Figure 6). As such, it is critical for investors to continue to press for better transparency and clarity on all relevant emissions scopes.

SEVERE STORMS AND PHYSICAL CLIMATE RISK

In addition to the large climate risks caused *by* the plastic lifecycle, it also is crucial for investors to recognize the physical risks climate change presents *to* existing and planned petrochemical infrastructure. This is especially true for the Corridor in the Gulf Coast, where most future capacity buildout in the U.S. is planned.

The Fourth National Climate Assessment 2018 indicates extensive risk of sea level rise threatening U.S. coastal regions, especially the southeast and Gulf Coast. The southeast chapter notes that:

> “Under higher emissions scenarios (RCP8.5), global sea level rise exceeding 8 feet (and even higher in the Southeast) by 2100 cannot be ruled out . . . .[224]
>
> Higher sea levels will cause the storm surges from tropical storms to travel farther inland than in the past, impacting more coastal properties. The combined impacts of sea level rise and storm surge in the Southeast have the potential to cost up to $60 billion each year in 2050 and up to $99 billion in 2090 under a higher scenario (RCP8.5). Even under a lower scenario (RCP4.5), projected damages are $56 and $79 billion in 2050 and 2090, respectively (in 2015 dollars, undiscounted).”[225]



Planet Tracker’s *Stormy Outlook* report found that 34 plastic production facilities in the Corridor are at, below, or slightly over 30 feet above sea level and face significant risks from sea level rise, flooding, and hurricanes – even under a below 2°C scenario (see Figure 7).[226] These risks have already been felt during events such as Hurricane Harvey, which caused $125 billion in total damage and shut down 68 plastic facilities and refineries in the Corridor – causing 75% of U.S. PE production to declare force majeure (when an event out of the company’s control prevents it from fulfilling its contractual obligations).[227] These severe storms present not only economic risks for companies (for example, Harvey reduced then-DowDupont’s 2017 third quarter

221. Science Based Targets, “Oil and Gas,” n.d., https://sciencebasedtargets.org/sectors/oil-and-gas#public-consultation-resources.

222. Global Reporting Initiative, “Sector Standards Project for Oil, Gas, and Coal: The First Pilot Project for the GRI Sector Program,” 2021, https://www.globalreporting.org/standards/standards-development/sector-standards-project-for-oil-gas-and-coal/.

223. Sustainability Accounting Standards Board, *Risks & Opportunities Associated with Single-Use Plastic in the Chemicals and Pulp & Paper Products Industries*, August 2020, https://www.sasb.org/wp-content/uploads/2020/08/Plastics-in-Chemical-and-Paper-Briefing-Paper.pdf.

224. U.S. Global Change Research Program, *Fourth National Climate Assessment*, 2018, https://nca2018.globalchange.gov/chapter/19/.

225. Ibid.

226. Planet Tracker, *Stormy Outlook*, https://planet-tracker.org/tracker-programmes/materials/plastics/#stormy-outlook.

227. Ibid.

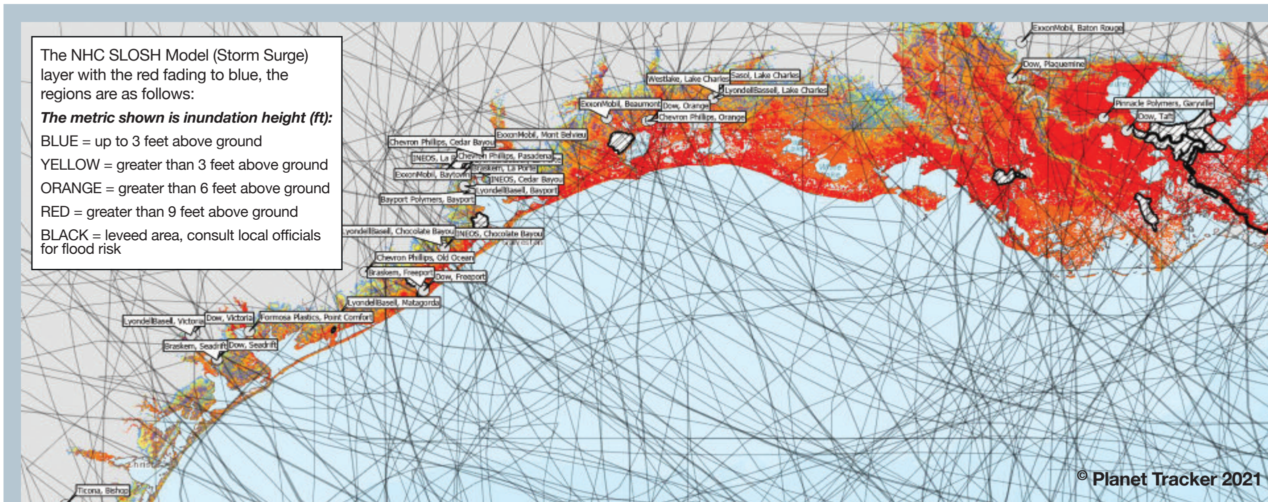


Figure 7: Storm Surge Risk Using SLOSH Model for the Plastic Production Corridor

SOURCE: Planet Tracker, *Stormy Outlook for US Plastics Refiners: Risk of Stranded Assets in the Gulf of Mexico*, Resins Briefing Paper (November 2020), https://planet-tracker.org/tracker-programmes/materials/plastics/#stormy-outlook.

Modelled Category 2 Hurricane Storm Surge Risk overlaid with lines from hurricanes, tropical storms, and depressions 1990 to 2020, NOAA.

earnings by $250 million)[228] and the larger petrochemical market, but also massive human health impacts that are most heavily felt by fence-line communities (which will be discussed in the next section).

This past year's Atlantic storm season was the most active on record,[229] with a total of 30 named storms accounting for $43 billion in damage in the U.S.[230] Hurricane Laura alone triggered the preemptive shutdown of six ethane crackers in Louisiana.[231] In total, five storms (Sally, Marco, Laura, Delta, and Beta) decreased key olefin and polyolefin capacity by 7% to 28% in Texas and Louisiana between August and September of 2020.[232]

Fortunately, no 2020 storm brought the degree of damage seen during Hurricane Harvey. However, storms and their impacts will intensify with climate change as storms become stronger, wetter, and slower to break down.[233,234] February 2021 brought a new and unprecedented weather event to the region: a snowstorm that saw freezing temperatures and rolling blackouts, further disrupting petrochemical operations.[235]

Investors are increasingly concerned about the physical risks of climate change faced by petrochemical infrastructure and have begun proactive engagement on the topic. In 2019, *As You Sow*'s related resolutions garnered a majority vote with Phillips 66 and strong votes with Chevron and Exxon.[236,237] CPChem responded to

228. Nivedita Bhattacharjee, "DowDuPont Set To Beat Quarterly Estimates as New Company," *Reuters*, October 26, 2017, https://www.reuters.com/article/us-dowdupont-results/dowdupont-set-to-beat-quarterly-estimates-as-new-company-idUSKBN1CV1GZ.

229. National Oceanic and Atmospheric Administration, "Record-Breaking Atlantic Hurrican Season Draws to an End: Improved Forecasts, Extensive Preparedness Helped Protect Lives and Property," press release, November 24, 2020, https://www.noaa.gov/media-release/record-breaking-atlantic-hurricane-season-draws-to-end.

230. Christopher Flavelle, "U.S. Disaster Costs Doubled in 2020, Reflecting Costs of Climate Change," *The New York Times*, January 7, 2021, https://www.nytimes.com/2021/01/07/climate/2020-disaster-costs.html.

231. Planet Tracker, *Stormy Outlook*, https://planet-tracker.org/tracker-programmes/materials/plastics/#stormy-outlook.

232. Ibid.

233. Henry Fountain, "Climate Change is Making Hurricanes Stronger, Researchers Find," *The New York Times*, last updated October 7, 2020, https://www.nytimes.com/2020/05/18/climate/climate-changes-hurricane-intensity.html.

234. Yale Environment 360, "Climate Change Is Causing Hurricanes to Break Down More Slowly Over Land," E360 Digest, November 17, 2020, https://e360.yale.edu/digest/climate-change-is-causing-hurricanes-to-break-down-more-slowly-over-land.

235. Michael Carmada, "Arctic Blast Hits US Olefins Output," Argus 50, February 16, 2021, https://www.argusmedia.com/en/news/2187366-arctic-blast-hits-us-olefins-output.

236. As You Sow, "Majority Vote – Phillips 66 Shareholders Strongly Back Petrochemical Climate-Risk Reduction," press release, May 8, 2020, https://www.asyousow.org/press-releases/2020/5/8/phillips-66-shareholder-proposal-climate-change.

237. As You Sow, "Shareholders Raise Alarms: Petrochemical Investments Are a Risky Bet," press release, May 27, 2020, https://www.asyousow.org/press-releases/2020/5/27/shareholders-raise-alarm-chevron-exxon-climate-change.

the resolutions by publishing new disclosures providing enhanced information about physical climate risk management in its existing and planned Gulf Coast operations, a positive first step for the company.[238,239] While response to shareholders from Exxon continues to be lackluster, in 2021 Dow Inc. agreed to increase its related disclosures.

Investors should be informed on the asset-level physical risks of company operations and which assets face the most risk on a forward-looking basis.

Enhanced and transparent physical risk disclosure is essential for shareholders to evaluate the risks that face their investments and companies. The methodologies and frameworks needed to facilitate such improvements have already been developed and are available. In 2018, Four Twenty Seven, Inc., and the European Bank for Reconstruction and Development published an in-depth report highlighting the need for asset-level disclosures and scenario planning on the impacts of physical risks from climate change.[240]

The Physical Risk of Climate Change (P-ROCC) framework, developed by Wellington and CalPERS in 2019, effectively incorporates these necessary advancements in physical climate risk and resilience disclosure.[241] The framework asks companies to evaluate and disclose physical risks in conjunction with climate scenario planning that evaluates risks on a short-, medium-, and long-term basis, and asks that companies provide transparent information about the data, models, and assumptions used to inform their scenarios. It is especially important to note that historical data is not suitable for assessing future climate risks. Investors should be informed on the asset-level physical risks of company operations and which assets face the most risk on a forward-looking basis. At a *minimum*, companies should provide detailed geographic and locational information for each company asset.[242]

KEY BENCHMARKS AND BEST PRACTICES ASSOCIATED WITH PETROCHEMICAL CLIMATE RISKS

Climate Impacts of Petrochemicals

Benchmark Questions:

- Does the company disclose all relevant scopes of emissions, including Scope 3 categories like end-of-life emissions, for its plastic or other petrochemical products and purchased feedstocks? Do the company's disclosures cover all business segments? If not, what is excluded and why?
- Does the company list petrochemicals or plastics as a climate-related opportunity? How does it support this claim?
- Does the company include all scopes of emissions and business segments in its GHG reduction goals?
- How does the company approach JV assets? Does it use an equity basis to account for emissions (for both disclosure and target-setting)?

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238. Chevron Phillips Chemical, *Managing Climate Change Risks: Safety and Planning for the Physical Risks of Climate Change*, November 2020, https://www.cpchem.com/sites/default/files/2020-11/Chevron%20Phillips%20Chemical%20-%20Managing%20Climate%20Change%20Risks%20-%202020.pdf.

239. As You Sow, "Chevron Phillips Publishes Climate Report in Response to Investor Concerns," press release, November 13, 2020, https://www.asyousow.org/press-releases/2020/11/13/chevron-phillips-climate-report-investor-concerns.

240. Emilie Mazzacurati, John Firth, and Sara Venturini, *Advancing TCFD Guidance on Physical Climate Risks and Opportunities*, May 2018, http://427mt.com/wp-content/uploads/2018/05/EBRD-GCECA_final_report.pdf.

241. CalPERS and Wellington Management, *Physical Risks of Climate Change (P-ROCC): A New Framework for Corporate Disclosures*, September 2019, https://www.wellington.com/uploads/2019/10/e01e2a4ed6fce336dce93f86f0af9883/physical-risks-of-climate-change_procc_framework.pdf.

242. Ibid.

Best Practice Example: Dow Inc. discloses both its upstream emissions from purchased products as well as the end-of-life emissions of the plastic resins it produces.[243] Furthermore, in its 2020 CDP Climate Response, Dow Inc. identifies the amount of Scope 1 emissions that are attributable to its packaging and specialty plastics division as well as the percentage of upstream emissions that come from purchased plastic feedstocks (ethane, ethylene, naphtha, etc.).

Physical Climate Risks Faced by Petrochemical Assets

Benchmark Questions:

- Does the company use scenario planning to assess physical climate risks faced by its assets? If so, does it evaluate on multiple time horizons (short-, medium-, and long-term)? Does the company evaluate physical risks' potential impact on revenue and profit?
- Does the company use historical climate data to predict future risk?
- What assumptions, data, methods, and models is the company using to assess physical risk? Are they up-to-date and forward looking?
- Where, geographically, are the company's assets located, and what are the physical attributes and climate risks identified in those areas? Which specific company assets are most at risk from climate-related impacts?
- Does the company discuss measures taken to increase the resiliency of its operations?
- Does the company discuss the role of federal and state support in its risk mitigation plans?
- Does the company discuss "lessons learned" from impacts during past severe weather events?

Best Practice Example: CPChem improved its physical climate risk disclosure in 2020 by issuing its *Managing Climate Change Risks* report.[244] Some companies like Dow Inc. provide the latitude and longitude of their facilities (reported in the 2020 CDP Climate Response). This serves as a *minimum* requirement in effective physical risk disclosure. While most companies' related disclosures remain far too general, new frameworks are available and should be used to enhance disclosure in this area, such as the P-ROCC framework described in the above section.[245]

HEALTH, ENVIRONMENTAL JUSTICE, AND INCREASING OPPOSITION

HAZARDOUS CHEMICALS AND HEALTH IMPACTS OF PETROCHEMICAL OPERATIONS

Some of the most important risks facing the petrochemical industry's planned expansion concern community health impacts and an eroding social license to operate. The negative human health impacts resulting from oil, gas, and petrochemical operations cannot be overstated. Though much attention has been given to impacts of fossil fuel combustion,[246] awareness of additional negative health impacts from petrochemical operations and the

243. Dow, *Sustainability Report 2019*, https://nshosting.dow.com/sustainability2019/includes/downloads/Sustainability_Report_2019.pdf.

244. Chevron Phillips Chemical, *Managing Climate Change Risks*, https://www.cpchem.com/sites/default/files/2020-11/Chevron%20Phillips%20Chemical%20-%20Managing%20Climate%20Change%20Risks%20-%202020.pdf.

245. CalPERS and Wellington Management, *Physical Risks*, https://www.wellington.com/uploads/2019/10/e01e2a4ed6fce336dce93f86f0af9883/physical-risks-of-climate-change_procc_framework.pdf.

246. Karn Vohra, Alina Vodonos, Joel Schwartz, et al., "Fossil Fuel Air Pollution Responsible for 1 in 5 Deaths Worldwide," Harvard T. H. Chan School of Public Health Center for Climate, Health, and the Global Environment, February 9, 2021, https://www.hsph.harvard.edu/c-change/news/fossil-fuel-air-pollution-responsible-for-1-in-5-deaths-worldwide/.

plastic lifecycle is growing.[247] It is estimated that open burning of waste in developing countries could account for as much as one-fifth of global annual deaths from ambient air pollution.[248] In particular, the open burning of plastics poses significant toxicity risks.[249]

Petrochemical facilities and related infrastructure use and emit dangerous chemicals, some of which are classified as Hazardous Air Pollutants (HAPs), a group of 187 regulated chemical species that are "known or suspected to cause cancer or other serious health effects… or adverse environmental effects."[250] A few examples of commonly emitted toxic pollutants and their associated health effects are discussed in Appendix C; however, these make up only a portion of a long and growing list of chemicals associated with the petrochemical supply chain, with impacts still being studied.[251] For example, the relationship between exposure to aromatics from petrochemical facilities – including benzene, toluene, and xylene – and various cancer risks like leukemia and lymphoma is an active area of research.[252]

In the U.S., the COVID-19 pandemic has exacerbated this public health burden – with research showing that areas with higher amounts of particulate matter (PM) and HAPs have higher rates of COVID-19 mortality.[253,254] This has further uncovered existing racial disparities in the U.S., with air pollution, which occurs in greater concentrations in historically segregated Black neighborhoods, causing COVID-19 to infect Black people with greater frequency and lethality than white people.[255,256] Research has shown that the Trump Administration's EPA COVID-19 enforcement freeze – in which requirements for pollution monitoring and reporting were removed – resulted in significant increases in air pollution and consequent increases in COVID-19 cases and mortality in areas with facilities that report hazardous emissions to the EPA.[257,258] Research on this topic is growing and underscores the inadequacy of current corporate disclosure and governmental regulation, monitoring, and enforcement to address these impacts.

247. David Azoulay, Priscilla Villa, Yvette Arellano, Miriam Gordon, Doun Moon, Kathryn Miller, and Kristin Thompson, *Plastic and Health: The Hidden Costs of a Plastic Planet*, February 2019, https://www.ciel.org/wp-content/uploads/2019/02/Plastic-and-Health-The-Hidden-Costs-of-a-Plastic-Planet-February-2019.pdf.

248. Mari Williams, Rich Gower, and Joanne Green, *No Time to Waste: Tackling the Plastic Pollution Crisis Before It's Too Late*, 2019, https://learn.tearfund.org/-/media/learn/resources/reports/2019-tearfund-consortium-no-time-to-waste-en.pdf.

249. Azoulay et al., *Plastic and Health*, https://www.ciel.org/wp-content/uploads/2019/02/Plastic-and-Health-The-Hidden-Costs-of-a-Plastic-Planet-February-2019.pdf, 43-45.

250. U.S. Environmental Protection Agency, "What Are Hazardous Air Pollutants?" last updated February 9, 2017, https://www.epa.gov/haps/what-are-hazardous-air-pollutants.

251. Azoulay et al., *Plastic and Health*, https://www.ciel.org/wp-content/uploads/2019/02/Plastic-and-Health-The-Hidden-Costs-of-a-Plastic-Planet-February-2019.pdf.

252. Calvin Jephcote, David Brown, Thomas Verbeek, and Alice Mah, "A Systematic Review and Meta-Analysis of Haematological Malignancies in Residents Living Near Petrochemical Facilities," *Environmental Health* 19 (2020), https://doi.org/10.1186/s12940-020-00582-1.

253. Xiao Wu, Rachel C. Nethery, Benjamin M. Sabath, et al., "Air Pollution and COVID-19 Mortality in the United States: Strengths and Limitations of an Ecological Regression Analysis," *Science Advances* 6, no. 45, (2020): p.eabd4940, https://projects.iq.harvard.edu/covid-pm.

254. Michael Petroni, Dustin Hill, Lylla Younes, et al., "Hazardous Air Pollutant Exposure as a Contributing Factor to COVID-19 Mortality in the United States," *Environmental Research Letters* 15, no. 9 (2020): 0940a9, https://doi.org/10.1088/1748-9326/abaf86.

255. Trymaine Lee, "First Pollution, Now Coronavirus: Black Parish in Louisiana Deals with 'a Double Whammy' of Death," *MSNBC*, April 23, 2020, https://www.msnbc.com/podcast/first-pollution-now-coronavirus-black-parish-louisiana-deals-double-whammy-n1189951.

256. Erika Edwards, "African Americans 'Disproportionately Affected' by Coronavirus, CDC Report Finds," *NBC News*, April 8, 2020, https://www.nbcnews.com/health/health-news/african-americans-disproportionately-affected-coronavirus-cdc-report-finds-n1179306

257. Sean Reilly, "Study of Emissions and Virus Deaths Implicates EPA Policy," *Greenwire*, July 17, 2020, https://www.eenews.net/greenwire/2020/07/17/stories/1063580943.

258. Claudia Persico and Kathryn R. Johnson, "The Effects of Increased Pollution on COVID-19 Cases and Deaths," *SSRN*, August 8, 2020, https://dx.doi.org/10.2139/ssrn.3633446.

INDUSTRY IMPACT ON MARGINALIZED, FENCE-LINE COMMUNITIES

Communities near fossil fuel and petrochemical facilities, known as fence-line communities, face heightened health risks – a long-term environmental justice issue. Research has shown that proximity to oil refineries in areas of dense industry buildout like Texas correlates to an increase in risk of all types of cancer.[259,260] Studies have further found that communities near petrochemical industrial complexes (such as the Corridor) face increased likelihood of additional adverse health outcomes such as effects on pregnancy and birth as well as asthma and other respiratory problems.[261]

SOURCE: Elizabeth Brossa, https://www.flickr.com/photos/elizabethbw/

The risks faced by these fence-line communities demonstrate a pattern of systemic injustice. In 2016, a study by the Center for Effective Government found that nearly 23 million U.S. residents (7.5% of population) live within one mile of one of the more than 12,500 hazardous chemical facilities that report to the EPA's Risk Management Program. Of this fence-line population, low-income communities and people of color face the highest risks.[262] The overall findings of the report are stark and highlight a high-priority concern for investors:[263]

- People of color are ***twice as likely*** to live within a fence-line zone as white people.
- Poor Black and Latino children are ***more than twice as likely*** to live within fence-line zones as white children above the poverty line.
- Nearly ***1 in 10*** schoolchildren attend one of the 12,000 schools within one mile of a chemical facility.
- Chemical facilities in communities of color have ***almost twice the rate*** of incidents compared to those in predominantly white neighborhoods.

These enormous disparities are easily seen in the Corridor. Residents of "Cancer Alley," which spans 85 miles of Louisiana along the Mississippi River in the eastern corner of the Corridor, face higher-than-average exposures to at least 15 hazardous chemicals regulated by the EPA.[264] In 2015, fine particle air pollution in Houston was responsible for 5,123 premature deaths and over $49 billion in associated economic damage.[265] East Houston communities, which have higher percentages of people of color and poverty rates, face toxicity levels from exposures that are three to 17 times higher than the more affluent white communities of west Houston.[266] Given that investor focus on social and racial justice has significantly increased since the tragic events that sparked global Black Lives Matter mobilizations during the summer of 2020, this issue's importance is likely to grow.

259. Stephen B. Williams, Yong Shan, Usama Jazzar, et al., "Proximity to Oil Refineries and Risk of Cancer: A Population-Based Analysis," *JNCI Cancer Spectrum* 4, no. 6 (December 2020): pka088, https://doi.org/10.1093/jncics/pkaa088.

260. Nick Powell, "Proximity to Texas Oil Refineries Increases Cancer Risk, Study Finds," *Houston Chronicle*, December 1, 2020, https://www.houstonchronicle.com/news/houston-texas/health/article/Proximity-to-Texas-oil-refineries-increases-cancer-15764845.php.

261. Montse Marques, Jose L. Domingo, Marti Nadal, and Marta Schuhmacher, "Health Risks for the Population Living Near Petrochemical Industrial Complexes. 2. Adverse Health Outcomes Other than Cancer," *Science of the Total Environment* 730 (August 2020): 139122, https://doi.org/10.1016/j.scitotenv.2020.139122.

262. Amanda Starbuck, "New Report, Interactive Map Show That People of Color and the Poor Are More Likely to Live Near Chemical Hazards," Center for Effective Government, January 21, 2016, https://www.foreffectivegov.org/blog/new-report-interactive-map-show-that-people-color-and-poor-are-more-likely-live-near-chemical-h.

263. Amanda Starbuck and Ronald White, *Living in the Shadow of Danger: Poverty, Race, and Unequal Chemical Facility Hazards*, n.d., https://www.foreffectivegov.org/sites/default/files/shadow-of-danger-highrespdf.pdf.

264. Pat Rizzuto, "'Cancer Alley' among Worst Areas for Chemical Risks, Groups Say," Bloomberg Law, June 22, 2020, https://news.bloomberglaw.com/environment-and-energy/poor-gulf-coast-exposed-to-worst-chemical-risks-groups-say?context=article-related.

265. Amanda Roy, Rachel Fullmer, Jeremy Proville, and Grace Tee Lewis, "Amid COVID-19, the Trump Administration Sets Dangerous Air Pollution Standards. What Is at Stake for Houstonians?" blog post, May 11, 2020, http://blogs.edf.org/texascleanairmatters/.

266. Union of Concerned Scientists and Texas Environmental Justice Advocacy Services, *Double Jeopardy in Houston: Acute and Chronic Chemical Exposures Post Disproportionate Risks for Marginalized Communities*, October 2016, https://www.ucsusa.org/sites/default/files/attach/2016/10/ucs-double-jeopardy-in-houston-full-report-2016.pdf.

UNAUTHORIZED EMISSIONS ARE ON THE RISE

All chemical facilities receive permits that authorize an allowable amount of air and water emissions from a facility. Air quality permits include emissions that arise from planned maintenance, startup, and shutdown (MSS) activities such as scheduled equipment repairs.[267]

Significant emissions occur outside of normal operations due to upset events and unplanned MSS and can be highly damaging. These emissions occur when "pollution abatement systems – such as scrubbers, baghouses, or flares that curtail emissions before they are released – fail to fully operate as the result of an unexpected malfunction, startup or shutdown."[268] Such emissions often exceed facilities' air quality permits and are thus referred to as "unauthorized" or "unpermitted" emissions. Importantly, unauthorized emission events are largely avoidable with the use of gas recovery systems, enhanced staffing and preventative maintenance, and emergency backup systems, among other risk mitigation strategies.[269] Not only do such emissions pose a large climate risk (such as methane venting or flaring), but they also often involve the release of the hazardous chemicals mentioned above and in Appendix C.

How often do these unauthorized emissions occur? A recent study from Environment Texas found that an unauthorized air pollution event occurred in an industrial facility every day of the year in Texas in 2019. Furthermore, these emissions have increased 155% from 2015 to 2019. In 2019, a total of 4,086 unauthorized pollution events resulted in the release of over 174 million pounds of air pollutants to surrounding communities.[270]

"In 2019, a total of approximately $1.8 million was assessed in penalties for these 119 unauthorized air pollution events, amounting to $0.01 per pound of unauthorized emissions in 2019."

In theory, these are illegal emissions that can be penalized under the Clean Air Act. However, the Texas Commission on Environmental Quality (TCEQ) and the State of Texas penalized less than 3% of the violations in 2019.[271] Environment Texas reported that "In 2019, a total of approximately $1.8 million was assessed in penalties for these 119 unauthorized air pollution events, amounting to $0.01 per pound of unauthorized emissions in 2019."[272]

One reason for the abysmal rate of enforcement is the "affirmative defense" loophole that allows companies to avoid financial penalties for emission violations if certain criteria are met – including that "the unauthorized emissions could not have been prevented, that all possible steps were taken to minimize the impact of the unauthorized emissions on ambient air quality, and that the emissions did not contribute to a condition of air pollution."[273] This counterintuitive loophole,

267. Catherine Fraser, *Illegal Air Pollution in Texas 2020: Air Pollution from Startups, Shutdowns, Malfunctions and Maintenance at Industrial Facilities in Texas in 2019*, https://environmenttexas.org/sites/environment/files/reports/TX_Pollution_2020_scrn.pdf.

268. Nikolaos Zirogiannis, Alex J. Hollingsworth, and David Konisky, "Air Pollution from Industrial Shutdowns and Startups a Grave Danger to Public Health," EcoWatch, February 15, 2018, https://www.ecowatch.com/air-pollution-startups-shutdowns-2534981679.html.

269. Fraser, Illegal Air Pollution in Texas 2020, https://environmenttexas.org/sites/environment/files/reports/TX_Pollution_2020_scrn.pdf.

270. Ibid.

271. Ibid.

272. Ibid.

273. Ibid.

which the EPA had plans to close, was kept intact by the Trump administration[274] and was claimed for 97% of the events in 2019.[275] Indeed, EPA enforcement has been at a record low.[276]

Finally, it is important to recognize that although unauthorized emissions from any one unplanned MSS event may be small in isolation, they pose serious chronic health risks in aggregation. For example, one study found that the direct and indirect particulate matter emissions from startup, shutdown, and malfunction events in Texas were estimated to cost $148 million worth of health impacts in 2015.[277] Furthermore, evidence has shown that these smaller events can lead to larger catastrophic chemical accidents, which the EPA has found to occur 150 times annually (about one every three days) on average.[278,279]

Severe Storms Cause Upset Emissions, Exacerbating Threats to Communities

Investors are increasingly concerned about the heightened community and human health risks presented by severe storms and the damaging upset emissions they bring before, during, and after such events. During shutdown and startup before and after a storm, facilities will often vent or flare unreacted chemicals into the atmosphere. During a storm, facilities may become inundated, increasing the risks of a chemical disaster. These emissions pose adverse health risks, especially to fence-line communities within “chemical clusters” where multiple facilities are aggregated, such as those in the Corridor (see Figure 8).

Flooding from recent storms like Hurricanes Harvey, Laura, and Delta caused plant shutdowns and the release of unpermitted, unsafe levels of pollutants. Hurricane Harvey led to the release of over 8.3 million pounds of unpermitted emissions (of which 2.2 million were emitted in a 48-hour timespan) and 150 million gallons of wastewater from sewage and refineries.[280] Nearby residents reported respiratory and other health concerns following such releases.[281,282] The EPA’s Inspector General issued a report following Hurricane Harvey concluding that lack of communication and air quality monitoring left impacted communities unaware

274. Nadja Popvich, Livia Albeck-Ripka, and Kendra Pierre-Louis, “The Trump Administration Rolled Back More than 100 Environmental Rules. Here’s the Full List,” *The New York Times*, January 20, 2021, https://www.nytimes.com/interactive/2020/climate/trump-environment-rollbacks-list.html.

275. Fraser, *Illegal Air Pollution*, https://environmenttexas.org/sites/environment/files/reports/TX_Pollution_2020_scrn.pdf.

276. Umair Irfan, “How Trump’s EPA Is Letting Environmental Criminals off the Hook, in One Chart,” Vox, February 27, 2019, https://www.vox.com/2019/1/16/18183998/epa-andrew-wheeler-environmental-policy-enforcement.

277. James Hatfield, Gabrielle Fekete, Seth Gerhart, and Julie Narimatsu, *EPA Needs to Improve Its Emergency Planning to Better Address Air Quality Concerns During Future Disasters*, U.S. Environmental Protection Agency Office of the Inspector General, Report No. 20-P-0062, December 16, 2019, https://www.epa.gov/sites/production/files/2019-12/documents/_epaoig_20191216-20-p-0062.pdf, 3-4.

278. U.S. Environmental Protection Agency, “National Compliance Initiative: Reducing Accidental Releases at Industrial and Chemical Facilities,” last updated February 24, 2021, https://www.epa.gov/enforcement/national-compliance-initiative-reducing-accidental-releases-industrial-and-chemical.

279. Ronald White, *The Impact of Chemical Facilities on Environmental Justice Communities: Review of Selected Communities Affected by Chemical Facility Incidents*, Union of Concerned Scientists, August 2018, https://www.ucsusa.org/sites/default/files/attach/2018/08/impact-chemical-facilities-on-environmental-justice-communities-ucs-2018.pdf.

280. Ari Phillips, *Preparing for the Next Storm: Learning from the Man-Made Environmental Disasters that Followed Hurricane Harvey*, Environmental Integrity Project, August 16, 2018, https://environmentalintegrity.org/wp-content/uploads/2018/08/Hurricane-Harvey-Report-8.16.18-final.pdf.

281. Frank Bajak and Lise Olsen, “Hurricane Harvey’s Toxic Impact Deeper Than Public Told,” AP, March 23, 2018, https://apnews.com/article/e0ceae76d5894734b0041210a902218d.

282. Rebecca Hersher, “Millions of Pounds of Extra Pollution Were Released before Hurricane Laura’s Landfall,” NPR, August 28, 2020, https://www.npr.org/sections/health-shots/2020/08/28/906822940/millions-of-pounds-of-extra-pollution-were-released-before-laura-made-landfall.

of risks.[283] Similarly, Hurricane Laura led to the release of more than 4 million pounds of excess air pollutants even before making landfall.[284]

In 2021, a Texas winter storm caused emissions of an estimated 3.5 million pounds of excess air pollutants over one week.[285,286] Large pollution events like this that occur over a short period of time present adverse health risks to the communities at the fence-line of petrochemical operations – risks further amplified by ineffective air quality monitoring.[287] As climate change increases the frequency and strength of extreme storms, and the costs they bring to companies and communities, it is crucial for investors to ask for transparent disclosure about the risks facing petrochemical company operations and their surrounding communities.

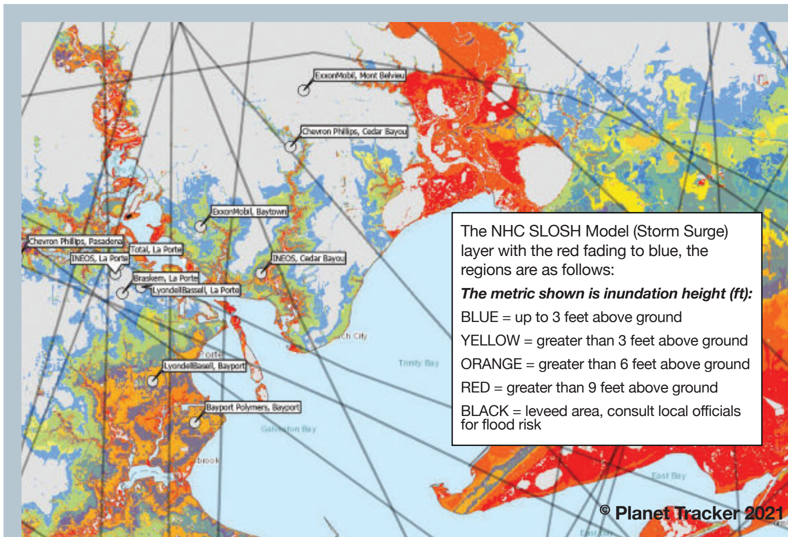

Figure 8: Storm Surge Risk Using SLOSH Model Threatening Plastic Production Facilities in Houston

SOURCE: Planet Tracker, *Stormy Outlook for US Plastics Refiners: Risk of Stranded Assets in the Gulf of Mexico*, Resins Briefing Paper (November 2020), https://planet-tracker.org/tracker-programmes/materials/plastics/#stormy-outlook.

Modelled Category 2 Hurricane Storm Surge Risk overlaid with lines from hurricanes, tropical storms, and depressions 1990 to 2020, NOAA.

CORPORATE DISCLOSURE MUST IMPROVE

Investors contend that human and community health risks from petrochemical operations should be directly addressed in company disclosures, including unauthorized emissions. However, company disclosures on this topic are at best cursory (the only pollutant required to be monitored at the fenceline for refineries is benzene)[288] and often misleading to shareholders.

Disclosure on community impacts is nearly absent from reporting of U.S. companies with large petrochemical operations. The most recent sustainability reports of CPChem,[289] Exxon,[290] and Dow Inc.[291] all discuss process safety, emergency preparedness training, diminishing incident rates, Community Advisory Panels, and community-focused donations but fail to disclose information about the community impacts their operations have on fence-line communities. For example, independent research found that facilities operated by these three companies were half of the top 10 emitters of unauthorized benzene and butadiene air pollution in Texas in

283. Hatfield et al., *EPA Needs to Improve*, https://www.epa.gov/sites/production/files/2019-12/documents/_epaoig_20191216-20-p-0062.pdf.

284. Hersher, "Millions of Pounds," https://www.npr.org/sections/health-shots/2020/08/28/906822940/millions-of-pounds-of-extra-pollution-were-released-before-laura-made-landfall.

285. Environmental Defense Fund, "Millions of Pounds of Air Pollution Released Because of Grid Failure, Freeze in Texas: Many Houston-Area Facilities Also Emitted Harmful Chemicals During Hurricane Harvey," February 23, 2021, https://www.edf.org/media/millions-pounds-air-pollution-released-because-grid-failure-freeze-texas#:~:text=(Houston%2C%20TX%20%E2%80%93%20February%2023,and%20freezing%20temperatures%20last%20week.

286. Laura Sanicola and Erwin Seba, "Texas Freeze Led to Release of Tons of Air Pollutants as Refineries Shut," *Reuters*, February 21, 2021, https://www.reuters.com/article/us-usa-weather-texas-emissions/texas-freeze-led-to-release-of-tons-of-air-pollutants-as-refineries-shut-idUSKBN2AL0AA.

287. U.S. Environmental Protection Agency, "EPA Winter Storms Uri and Viola: Update #2," February 18, 2021, https://response.epa.gov/sites/15082/files/Winter%20Storms%20Report%202%2002182021.pdf.

288. American Fuel & Petrochemical Manufacturers, "EPA's Fenceline Monitoring Program," n.d., https://www.afpm.org/sites/default/files/issue_resources/Fenceline-Monitoring-for-Benzene-B-FAQ.pdf.

289. Chevron Phillips Chemical, *Embracing Progress*, https://www.cpchem.com/2019Report/assets/downloads/Embracing_Progress_CPCHEM_2019_sustainability_report.pdf.

290. ExxonMobil, *Sustainability Report Highlights*.

291. Dow, *Sustainability Report 2019*, https://nshosting.dow.com/sustainability2019/includes/downloads/Sustainability_Report_2019.pdf.

2019.[292] Furthermore, while companies disclose total emissions of criteria air pollutants like sulfur dioxide (SO_2), NOx, and VOCs (some in a general performance data table), none provides context to understand the significance of such data or discuss the portion of emissions that were beyond permitted levels or the specific risks that these emissions pose to surrounding communities.

While CPChem published a report – *Managing Climate Change Risks* – in response to a shareholder request, providing a positive first step in better physical risk disclosure from the company,[293] the report provides no further detail about the associated community health impacts seen during severe weather.[294] Investors contend that such information should not have to be found through third-party analysis or other watchdog groups, but instead should be provided by the company.

GRASSROOTS OPPOSITION IS ERODING SOCIAL LICENSE TO OPERATE

Industry's plans to continue development of petrochemical activities in the Gulf Coast and the Ohio River Valley face growing opposition from grassroots organizations and community groups. Sparked by rising awareness of the adverse impacts posed both by climate change and petrochemical pollution on fence-line communities, companies face an eroding social license to operate in these areas. Some opposition has stemmed from larger organizations like Earthjustice, Environmental Defense Fund (EDF), and the Union of Concerned Scientists. For example, the Public Health Air Quality Act of 2020[295] is a recent bill that seeks to significantly expand hazardous pollutant monitoring. The bill directly addresses disproportionate impacts felt by fence-line communities and would "require the EPA to implement immediate fence-line monitoring for toxic air pollutants at facilities contributing to high local cancer rates and other health threats from dangerous pollutants."[296] Furthermore, 10 environmental, community, and environmental justice groups recently challenged the Trump Administration EPA's new Clean Air Act rule for steam crackers for failing to protect public health.[297]

Local opposition groups play an undeniably powerful and growing role. Groups like Healthy Gulf,[298] Earthworks,[299] Waterkeeper Alliance,[300] Environmental Integrity Project,[301] FracTracker Alliance,[302] and the Center for Biological Diversity[303] have all supported community efforts to oppose the petrochemical buildout in the Gulf Coast. Portland

292. Fraser, *Illegal Air Pollution*, https://environmenttexas.org/sites/environment/files/reports/TX_Pollution_2020_scrn.pdf.

293. Chevron Phillips Chemical, *Managing Climate Change Risks*, https://www.cpchem.com/sites/default/files/2020-11/Chevron%20Phillips%20Chemical%20-%20Managing%20Climate%20Change%20Risks%20-%202020.pdf.

294. As You Sow, "Chevron Phillips Publishes Climate Report," https://www.asyousow.org/press-releases/2020/11/13/chevron-phillips-climate-report-investor-concerns.

295. Gretchen Goldman, "Science Group Supports Bill to Expand Pollution Monitoring for At-Risk Communities," Union of Concerned Scientists, July 30, 2020, https://www.ucsusa.org/about/news/science-group-supports-bill-expand-pollution-monitoring-risk-communities.

296. Andrew Donnelly, "Blunt Rochester, Duckworth, and Congressional Environmental Justice Leaders Introduce Bill to Improve Air Quality Monitoring, Protect Front-Line Communities," press release, July 29, 2020, https://bluntrochester.house.gov/news/documentsingle.aspx?DocumentID=2508.

297. Julie Grant, "Enviro Groups Challenge EPA's New Air Rule for Ethane Crackers," *The Allegheny Front*, September 18, 2020, https://www.alleghenyfront.org/enviro-groups-challenge-epas-new-air-rules-for-ethane-crackers/.

298. Healthy Gulf, n.d., https://www.healthygulf.org/.

299. Earthworks, "Oil and Gas Health Effects," 2019, https://www.earthworks.org/issues/oil_and_gas_health_effects/.

300. Diane Wilson, "Report Shows Plastic Pollution a Threat to Texas Gulf Coast," Waterkeeper Alliance, August 9, 2018, https://waterkeeper.org/news/report-shows-plastic-pollution-a-threat-to-texas-gulf-coast/.

301. Environmental Integrity Project, "The Oil and Gas Industry Has Grown Dramatically over the Last Decade," 2021, https://environmentalintegrity.org/what-we-do/oil-and-gas/.

302. FracTracker Alliance, "Petrochemicals," 2020, https://www.fractracker.org/categories/by-content/petrochemicals/.

303. Center for Biological Diversity, "The Plastic-Production Problem: End the Fracking-Fueled Plastic Boom," n.d., https://www.biologicaldiversity.org/campaigns/plastic-production/index.html.

Citizens United,[304] One Breath Partnership,[305] Environment Texas,[306] Texas Environmental Justice Advocacy Services,[307] and the Lone Star Chapter of the Sierra Club[308] are involved in grassroots movements in Texas. In Louisiana, groups like the Louisiana Bucket Brigade,[309] RISE St. James,[310] and the Louisiana Environmental Action Network[311] have long worked to protect community residents, including by opposing the petrochemical development of companies like Formosa Plastics in St. James, Louisiana (see case study below), which has proposed a new 2,000-acre plastic facility.[312]

Planned development in the Ohio River Valley is already seeing increased opposition from grassroots groups like the Concerned Ohio River Residents[313] and Ohio River Valley Environmental Coalition[314] as well as from larger organizations such as Penn Environment[315] and the Ohio River Valley Institute, which has published recent research contradicting the claims of industry-sponsored economic impact studies on petrochemical development in the Ohio River Valley.[316]

Case Study: Cancer Alley, Louisiana, and Formosa Plastics

"Cancer Alley" is an 85-mile stretch of land between Baton Rouge and New Orleans along the Mississippi River in Louisiana. More than 200 petrochemical plants are located within Cancer Alley; not coincidentally, so too are seven of the nation's top 10 census tracts with the highest cancer risk.[317,318] Unsurprisingly, the areas that face the highest cancer risks are predominantly Black and low-income communities.[319] A recent analysis by ProPublica found that Louisiana has granted permits for the construction or expansion of an additional seven facilities since 2015 in Cancer Alley, with five now awaiting approval by the Louisiana Department of Environmental Quality.[320]

One of the most concerning projects is the $9.4 billion Sunshine Project from Taiwanese-owned Formosa Plastics in the 5th district of St. James Parish.[321] The facility is slated to be built less than two miles from a Black church and public school in a census tract (405) that is 91% African American. The community directly across the river from Formosa Plastics' proposed site (Census Tract 404) would be severely impacted as well and is 61% African

304. Portland Citizens United, 2021, https://portlandcitizensunited.com/.

305. One Breath Partnership, n.d., https://onebreathhou.org/.

306. Environment Texas, "Texas Clean Air Project," n.d., https://environmenttexas.org/feature/txe/texas-clean-air-project.

307. Texas Environmental Justice Advocacy Services, n.d., https://www.tejasbarrios.org/.

308. Sierra Club, Lone Star Chapter, 2021, https://www.sierraclub.org/texas.

309. Louisiana Bucket Brigade, 2021, https://labucketbrigade.org/.

310. RISE St. James Facebook Page, https://www.facebook.com/risestjames/.

311. Louisiana Environmental Action Network, 2021, https://leanweb.org/.

312. Stop Formosa Plastics, n.d., https://www.stopformosa.org/.

313. Concerned Ohio River Residents, n.d., https://www.concernedohioriverresidents.org/.

314. Ohio Valley Environmental Coalition, "Appalachian Storage Hub/Petrochemical Complex," n.d., https://ohvec.org/appalachian-storage-hub-petrochemical-complex/.

315. Penn Environment, "Don't Frack Pennsylvania!," n.d., https://pennenvironment.org/programs/pae/dont-frack-pennsylvania.

316. Ohio River Valley Institute, n.d., https://ohiorivervalleyinstitute.org/.

317. Antonia Juhasz, "Louisiana's 'Cancer Alley' Is Getting Even More Toxic—But Residents Are Fighting Back," *Rolling Stone*, October 30, 2019, https://www.rollingstone.com/politics/politics-features/louisiana-cancer-alley-getting-more-toxic-905534/.

318. Lee, "First Pollution," https://www.msnbc.com/podcast/first-pollution-now-coronavirus-black-parish-louisiana-deals-double-whammy-n1189951.

319. Tristan Baurick, Lylla Younes, and Joan Meiners, "Welcome to 'Cancer Alley,' Where Toxic Air Is about to Get Worse," *ProPublica*, October 30, 2019, https://www.propublica.org/article/welcome-to-cancer-alley-where-toxic-air-is-about-to-get-worse.

320. Lylla Younes, Al Shaw, and Claire Perlman, "In a Notoriously Polluted Area of the Country, Massive New Chemical Plants Are Still Moving In," *ProPublica*, October 30, 2019, https://projects.propublica.org/louisiana-toxic-air/.

321. *The Sunshine Project*, n.d., https://www.sunshineprojectla.com/.

American.[322] Consisting of 14 separate production units, the project is expected to double the amount of toxins currently released into St. James' air and would release more carbon dioxide than any of the 219 U.S. oil and gas projects proposed in 2019.[323] The Sunshine Project would be Formosa's third petrochemical complex in the U.S. with the other two in Point Comfort, Texas, and Baton Rouge, Louisiana.[324]

The looming impacts that the inaptly named Sunshine Project would put on these districts, already marginalized, led to the creation of RISE St. James in 2018, a grassroots community group that opposes petrochemical development in St. James parish. Using public protests, legal challenges, council engagement, and leveraging relationships with other groups like the Louisiana Bucket Brigade, Tulane Environmental Law Clinic, Center for Constitutional Rights, Earthjustice, and the Center for Biological Diversity, the movement is seeing signs of success and growing momentum. In 2019, the group helped to force Chinese-owned Wanhua Chemical Group to abandon plans for a new petrochemical plant in St. James.[325]

More recently, the group has focused its aim at Formosa's Sunshine Project, holding protests near the planned building site and submitting a letter to the Parish Council demanding an end to petrochemical infrastructure development in the parish.[326] In a landmark decision, the Sunshine Project was indefinitely delayed after the U.S. Army Corps of Engineers suspended one of the project's key permits due to lawsuits filed by the Center for Biological Diversity, RISE St. James, Louisiana Bucket Brigade, and Healthy Gulf on inadequate environmental impact assessment.[327,328] The project's air permits were remanded back to the Louisiana Department of Environmental Quality by a state judge.[329]

This case garnered massive attention from the public and media, with Sharon Lavigne (founder of RISE St. James) being featured in *The Women of Cancer Alley* film series.[330] Other community members from Louisiana have spoken in Washington, D.C., and Tokyo against petrochemical development in Cancer Alley.[331] This and similar cases serve as signposts of the industry's declining social license.[332]

322. U.S. Environmental Protection Agency, 2014-2018 American Community Survey data, accessed via EJSCREEN: EPA's Environmental Justice Screening and Mapping Tool on Mar 11, 2021, https://ejscreen.epa.gov/mapper/.

323. Juhasz, "Louisiana's 'Cancer Alley,'" https://www.rollingstone.com/politics/politics-features/louisiana-cancer-alley-getting-more-toxic-905534/.

324. Formosa Plastics, "Our Company: Our Operations," n.d., https://www.fpcusa.com/company/operations/index.html.

325. Juhasz, "Louisiana's 'Cancer Alley,'" https://www.rollingstone.com/politics/politics-features/louisiana-cancer-alley-getting-more-toxic-905534/.

326. Ibid.

327. S&P Global Platts, "Formosa Taiwan Unit Indefinitely Delays $9.4 Billion Louisiana Petrochemical Complex," n.d., https://www.spglobal.com/platts/en/market-insights/latest-news/petrochemicals/112320-formosa-taiwan-unit-indefinitely-delays-94-billion-louisiana-petrochemical-complex.

328. Center for Biological Diversity, "Army Corps Suspends Permit for Formosa Plastics' Controversial Louisiana Plant," November 4, 2020, https://biologicaldiversity.org/w/news/press-releases/army-corps-suspends-permit-for-formosa-plastics-controversial-louisiana-plant-2020-11-04/.

329. David J. Mitchell, "Judge Delays Crucial Permit for Formosa Plastics Plant; Requires Deeper Analysis of Racial Impacts," *The Advocate*, November 18, 2020, https://www.theadvocate.com/baton_rouge/news/article_8b2e3284-29d8-11eb-9442-6f8b45c7fcb1.html.

330. Center for Constitutional Rights, "Cancer Alley," April 17, 2019, https://ccrjustice.org/cancer-alley.

331. Julia Dermansky, "Louisiana's Cancer Alley Residents Take the Fight for Environmental Justice on the Road," DeSmog, July 8, 2019, https://www.desmogblog.com/2019/07/08/louisiana-cancer-alley-environmental-justice-dc-tokyo.

KEY BENCHMARKS AND BEST PRACTICES ASSOCIATED WITH HEALTH AND ENVIRONMENTAL JUSTICE

Benchmark Questions:

- Does the company have protocols and strategies that mitigate against the human health risks associated with emissions from its petrochemical operations? If so, does the strategy include both routine and unpermitted levels of emissions?
- Does the company acknowledge or disclose the human health risks associated with petrochemical operations that arise through unplanned emissions during (damage, leaks, or releases), in preparation for (shutdowns), or following (startups) severe weather events?
- Does the company provide air quality monitoring at the fenceline, ensure that monitoring remains online during emergencies, and make this data publicly available?
- Does the company report plant-by-plant estimated emissions to air and water resulting from upset events or leaks that occur because of extreme weather, severe storms, and sea level rise for existing and planned petrochemical facilities in the Gulf Coast? If so, does the company discuss whether such emissions surpassed permitted levels, the impacts to public health and the environment of neighboring communities, and the company's response to address such releases after they occurred? Does the company discuss future expectations for such emissions?
- Does the company provide lessons learned from past incidents experienced by its facilities during severe weather, including how emissions monitoring can be improved, where emissions surpassed permitted levels, and what can be done to prevent such releases in future scenarios (e.g., impacts from Hurricanes Harvey, Laura, and Delta or Winter Storms Uri and Viola)?
- Does the company disclose its strategy for adequately communicating with neighboring communities and other key stakeholders before, during, and after emergency situations?
- Does the company discuss the socio-economic demographics of the communities near which it operates?
- Does the company discuss plans or targets for reducing the absolute emissions of HAPs and other harmful air toxics?

Best Practice Example: Currently, company disclosure on community health impacts has been virtually absent. One sign of progress is Shell's 2017 agreement with the Clean Air Council and Environmental Integrity Project to install continuous air monitoring around its new cracker plant in Monaca, Pennsylvania. However, this occurred only because of a challenge to the plant's air quality permits and two years of negotiation between the environmental groups and Shell.[333] Investors contend that company actions to address, mitigate, and disclose these impacts are critical components of its corporate responsibility.

332. Lily Moore-Eissenberg, "Nurdles All the Way Down," *Texas Monthly* (October 2019), https://waterkeeper.org/magazines/be-the-change-volume-16/nurdles-all-the-way-down/.

333. Marie Cusick, "Shell, Environmental Groups Reach Deal on Air Monitoring for Ethane Cracker," August 28, 2017, https://stateimpact.npr.org/pennsylvania/2017/08/28/shell-environmental-groups-reach-deal-on-air-monitoring-for-ethane-cracker/.

CONCLUSION

The risks of the ongoing fossil-based plastic buildout are apparent and considerable, and the timing for robust investor engagement on such issues is critical. The impacts of the COVID-19 pandemic have further exposed these risks, and society is becoming increasingly opposed to industry's attempts to lock in additional plastic production for the coming decades. Now is a key moment to clarify what is at stake.

Petrochemicals – most notably, plastics – are set to be the largest driver of marginal oil demand growth in the coming decades, but that growth comes with significant financial and ESG concerns that may reduce growth potential. In the U.S., the plastic production market is already in a state of overcapacity, with more investment planned, the potential for declining margins, and demand growth in question. Indeed, assumed growth in fossil plastic consumption in the Global South may not meet high expectations given global momentum toward a circular economy, as consumers, markets, governments, and other stakeholders seek to address the plastic pollution crisis. While some petrochemical companies have made commitments to "circular" solutions, scrutiny is merited to assure such efforts are meaningful.

Industry's continued investment in the plastic buildout also raises concerns as to society's climate and environmental justice goals. GHG and other harmful emissions associated with the plastic lifecycle are significant, increasing, and felt most heavily by marginalized communities. Climate change-strengthened severe storms catalyze these environmental and public health risks.

As these issues gain more attention, further research and transparency are needed. The benchmark questions found in each section above are provided as a starting point to assist investors in assessing petrochemical company investments, practices, and remaining risks. As the transition to a Paris-aligned, circular, sustainable, and equitable future continues to materialize, companies involved in the production of petrochemical products can ensure shareholder value through proactive engagement and public disclosure on the critical, evolving ESG issues raised in this report.

APPENDIX A: ADDITIONAL RESOURCES

SHIFTING ECONOMICS

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– Peter G. Levi and Jonathan M. Cullen, "Mapping Global Flows of Chemicals: From Fossil Fuel Feedstocks to Chemical Products. *Environmental Science & Technology* 52, no. 4 (2018): 1725-1734. https://doi.org/10.1021.acs.est.7b04573.

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– Tom Sanzillo, Kathy Hipple, and Suzanne Mattei, *Proposed PTTGC Petrochemical Complex in Ohio Faces Significant Risks: Financial Outlook Dims as Financial and Policy Pressures Mount*, Institute for Energy Economics and Financial Analysis, March 2020, https://ieefa.org/wp-content/uploads/2020/03/Proposed-PTTGC-Complex-in-OH-Faces-Risks_March-2020.pdf.

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– Stephanie B. Borrelle, Jeremy Ringma, Kara Lavender Law, et al., "Predicted Growth in Plastic Waste Exceeds Efforts to Mitigate Plastic Pollution," *Science* 369, no. 6510 (September 2020): 1515-1518, https://doi.org/10.1126/science.aba3656.

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– Conrad MacKerron, Kelly McBee, and David Shugar, Waste and Opportunity 2020: Searching for Corporate Leadership, As You Sow, 2020, https://www.asyousow.org/reports/waste-and-opportunity-2020-searching-corporate-leadership.

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– Andrew N. Rollinson and Jumoke Oladejo, *Chemical Recycling: Status, Sustainability, and Environmental Impacts*, Global Alliance for Incinerator Alternatives, 2020, https://doi.org/10.46556/ONLS4535.

– Closed Loop Partners, *Navigating Plastic Alternatives in a Circular Economy: A Closed Loop Partners Report*, 2020, https://www.closedlooppartners.com/wp-content/uploads/2020/12/Navigating-Plastic-Alternatives-In-a-Circular-Economy.pdf.

– Closed Loop Partners, *Accelerating Circular Supply Chains for Plastics: A Landscape of Transformational Technologies That Stop Plastic Waste, Keep Materials in Play and Grow Markets*, 2019, https://www.closedlooppartners.com/wp-content/uploads/2021/01/CLP_Circular_Supply_Chains_for_Plastics_Updated.pdf.

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APPENDIX B: PLASTIC LIFECYCLE STAGES AND ASSOCIATED GHG EMISSIONS

Given the complex, global nature of the plastic industry, all GHG lifecycle emissions analyses for plastics rely on a wide array of complicated assumptions. The enormous variety of plastic resins (such as specialty plastics) make it extremely difficult to account for the emissions profile of every resin. Therefore, analysis typically includes the five key thermoplastic families that make up 85% of plastic production: polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), polyethylene terephthalate (PET), and polyethylene (PE).[334] Differences in emissions profiles for these plastics can also occur based on feedstock (mainly ethane or naphtha), region of production, and emissions boundaries applied (such as how downstream, end-of-life emissions are allotted, if at all). Additional elements and assumptions that impact the estimated emissions attributable to plastic include how plastic resin pellets are manufactured into final plastic products, if additives are included (common plasticizers and other plastic additives are often used to enhance performance of final products), and end-of-life pathways (whether a plastic product is recycled, landfilled, incinerated with or without energy recovery, or open burned).

While averaged lifecycle emission factors are useful for projecting the future emissions expected from industry's growth, it is important to understand that distinct climate risks exist along every stage of the plastic lifecycle. A detailed study published in *Nature Climate Change* found that 61% of emissions from the plastic lifecycle are from resin production, 30% from resin-to-product conversion, and 9% from end-of-life.[335]

Resin Production

The resin production stage (which covers extraction of fossil fuels to the production of plastic resin pellets) accounts for the highest amount of emissions according to the *Nature* study (61% of total). This stage includes emissions from the extraction of oil and natural gas from the ground, subsequent processing and transportation of feedstock, production of olefins (mainly through ethane steam cracking at cracker plants), and conversion to polyolefin resin pellets.[336]

Accounting for the contribution of emissions from oil and gas extraction to the plastic lifecycle is complicated by the high variation in both the emissions intensity of a barrel of oil and in the amount of ethane in a stream of

334. Hamilton et al., *Plastic & Climate*, https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf, 15.
335. Zheng and Suh, "Strategies to Reduce," https://www.nature.com/articles/s41558-019-0459-z.
336. Hamilton et al., *Plastic & Climate*, https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf.

fracked gas that is used as plastic feedstock.[337] Furthermore, natural gas systems, which provide the main plastic feedstock in the U.S. (ethane), include emissions from hydraulic fracturing, trucking of related chemicals and wastes, fractionation and storage of natural gas liquids (NGLs), as well as pipeline transport of NGLs to cracker plants.[338] Estimating emissions from these natural gas systems has been a challenge due to fugitive emissions from leaks, flaring, and venting – the subject of *As You Sow*'s *End of the Line* report and *Disclosing the Facts* series.[339,340] CIEL uses the conservative estimate that 1.8% of the 204.8 million tonnes CO_2e from U.S. natural gas systems in 2015 can be attributed to the plastic lifecycle.[341] Furthermore, CIEL and others have noted that the EPA's reported emissions from natural gas systems is heavily underestimated.[342] For example, research from EDF found that methane leaks in the U.S. from 2012 to 2018 were 60% higher than the EPA's estimate.[343]

Steam cracking is by far the most emissions-intensive activity within the resin production stage. Steam crackers use heat and pressure to "crack" feedstocks (ethane, naphtha, and other NGLs) into High Value Chemicals, including ethylene and propylene, the building blocks of the plastic industry.[344] Cracking furnaces need large amounts of energy to crack ethane – this high energy usage results in high levels of GHG emissions.[345] CIEL's analysis of 24 U.S. industrial facilities with ethylene crackers in 2015 found that ethylene cracking alone amounted to 17.5 million tonnes CO_2e, about a third of total GHG emissions released from these complexes.[346] Furthermore, 12 planned cracker projects in the US are estimated to produce an additional 21.2 million tonnes CO_2e per year.[347,348]

Plastic Product Manufacturing

This conversion stage involves the manufacturing of final plastic products from the base plastic resin pellets. These processes include mainly blow molding, injection molding, and extrusion and have been estimated to produce 535 million tonnes CO_2e in 2015 (30% of total).[349] Most analyses assume the use phase of a plastic product has no associated emissions.

337. Ibid, 21-31.
338. Ibid, 21-38.
339. Lila Holzman and Danielle Fugere, *The End of the Line: A Review of Methane Emission Reduction Practices in the Natural Gas Distribution Sector*, July 2018, https://www.asyousow.org/reports/2018/7/10/end-of-the-line.
340. Richard Liroff, Danielle Fugere, Steven Heim, Lila Holzman, and Benjamin Davis, D*isclosing the Facts: Transparency and Risk in Water & Chemicals Management for Hydraulic Fracturing Operations*, 2019, http://disclosingthefacts.org/.
341. Hamilton et al., *Plastic & Climate*, https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf, 21-31.
342. Ibid, 33-34.
343. Environmental Defense Fund, "Major Studies Reveal 60% More Methane Emissions," n.d., https://www.edf.org/climate/methane-studies.
344. Hamilton et al., *Plastic & Climate*, https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf, 33-34.
345. Ibid, 33-34.
346. Ibid, 46.
347. Ibid, 33-34.
348. Environmental Integrity Project, "Tracking Oil and Gas Infrastructure Emissions," February 26, 2021, https://environmentalintegrity.org/oil-gas-infrastructure-emissions/.
349. Zheng and Suh, "Strategies to Reduce," https://www.nature.com/articles/s41558-019-0459-z.

End-of-Life

Various end-of-life treatments of plastic products result in higher or lower climate impacts. In the U.S., the main end-of-life pathways assumed for plastic are recycling (9%), landfill (75%), and waste-to-energy (WTE) incineration (16%), with WTE incineration being the most emissions-intensive.[350] The previously mentioned *Nature* study found that these pathways accounted for 161 million tonnes CO_2e (9% of total) in 2015.[351] These emissions have likely increased since then, as the most current EPA data show that total U.S. plastic waste generation has increased by 1.2 million tons from 2015 to 2018, while the amount recycled has slightly decreased.

Globally, The Pew Charitable Trusts and SYSTEMIQ's *Breaking the Plastic Wave* report found that the world mismanaged 41% of its plastic waste in 2016 and that the amount would grow to 56% by 2040 under a business-as-usual scenario.[352] Plastic waste mismanagement includes terrestrial leakage, ocean leakage, and open burning. In particular, open burning produces significantly more emissions than WTE incineration. Furthermore, recent studies have shown that the US is the largest producer of plastic waste and third-largest contributor to coastal plastic pollution.[353,354] Although most developed nations do not have significant open burning, the developing economies that are forecast to increase plastic consumption are not equipped with appropriate end-of-life infrastructure, posing a massive climate risk to expanding plastic production.[355] Furthermore, the advent of new technologies like chemical recycling or bioplastics (covered earlier in this report) requires that such additional end-of-life pathways also be evaluated for their emissions impact. The *Breaking the Plastic Wave* report provides useful data for understanding the emissions variability of the different pathways to consider.[356]

350. U.S. Environmental Protection Agency, "Plastics: Material-Specific Data," | https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data.
351. Zheng and Suh, "Strategies to Reduce," https://www.nature.com/articles/s41558-019-0459-z.
352. The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave*, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.
353. Laura Parker, "U.S. Generates More Plastic Trash Than Any Other Nation, Report Finds," October 30, 2020, https://www.nationalgeographic.com/environment/2020/10/us-plastic-pollution/#:~:text=New%20research%20shows%20that%20the,plastic%20waste%20in%20the%20world.&text=The%20U.S.%20also%20ranks%20as,mismanaged%20waste%20to%20its%20shorelines.
354. George Leonard and Nick Mallos, "Stopping Ocean Plastic Pollution Starts with Us," October 30, 2020, https://oceanconservancy.org/blog/2020/10/30/stopping-ocean-plastic-pollution-starts-us/.
355. Ellie Moss, Alex Eidson, and Jenna Jambeck, *Sea of Opportunity: Supply Chain Investment Opportunities to Address Marine Plastic Pollution*, February 2017, http://encouragecapital.com/wp-content/uploads/2017/03/Sea-of-Opportunity-Plastics-Report-full-report.pdf.
356. The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave*, https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.

APPENDIX C: COMMON POLLUTANTS ASSOCIATED WITH PETROCHEMICAL OPERATIONS

Benzene, a flammable Hazardous Air Pollutant (HAP) that ranks as one of the top 20 chemicals produced by volume, is used heavily for the production of plastics, synthetic fibers, and other chemicals.[357] The human health impacts of benzene exposure are severe, with the World Health Organization concluding that there is no safe level of exposure.[358] On a short-term basis, benzene can cause headaches, tremors, drowsiness, dizziness, and even death within several minutes or hours if exposure levels are high enough. Long-term exposure has been found to lead to a variety of adverse health impacts including blood disorders, birth defects, cancer, and damage to reproductive systems.[359,360] A recent Environment Texas report found that the top unauthorized emitter of both benzene and particulate matter in 2019 was the Intercontinental Terminals Deer Park Terminal, which stores chemicals for several large oil and gas companies like Exxon, Chevron, and Phillips 66.[361,362]

Butadiene is also a highly flammable HAP used in the production of plastics, rubber, and other chemicals. Short-term exposure can cause irritation of the eyes and throat, headaches, fatigue, decreased blood pressure and pulse, central nervous system damage, and unconsciousness. Long-term exposure can cause cancer, and several studies have correlated exposure to the likelihood of developing leukemia.[363,364]

Other HAPs associated with plastic production include styrene, toluene, ethane, propylene, and propylene oxide – these are discussed in a CIEL's *Plastic & Health* report.[365] The report also covers a group of hazardous chemicals called polycyclic aromatic hydrocarbons (PAHs), the toxic nature of plasticizers, and other plastic additives that pose serious risks during the use and end-of-life phases of the plastic lifecycle.[366] **Ethylene oxide**, another HAP involved as a chemical intermediate to the production of PET, is receiving increasing attention after the EPA updated its toxicity assessment.[367]

Oil refineries and natural gas systems play key roles in the production of petrochemicals, thus hazardous emissions from these operations also need to be recognized as risks for the industry. These include **SO_2**, **NOx**, **PM**, **inorganic compounds**, and other **VOCs**.[368]

357. Centers for Disease Control and Prevention, "Facts about Benzene," April 4, 2018, https://emergency.cdc.gov/agent/benzene/basics/facts.asp.
358. World Health Organization, *Exposure to Benzene: A Major Public Health Concern*, 2019, https://apps.who.int/iris/bitstream/handle/10665/329481/WHO-CED-PHE-EPE-19.4.2-eng.pdf?ua=1.
359. Azoulay et al., *Plastic and Health*, https://www.ciel.org/wp-content/uploads/2019/02/Plastic-and-Health-The-Hidden-Costs-of-a-Plastic-Planet-February-2019.pdf, 18-19.
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