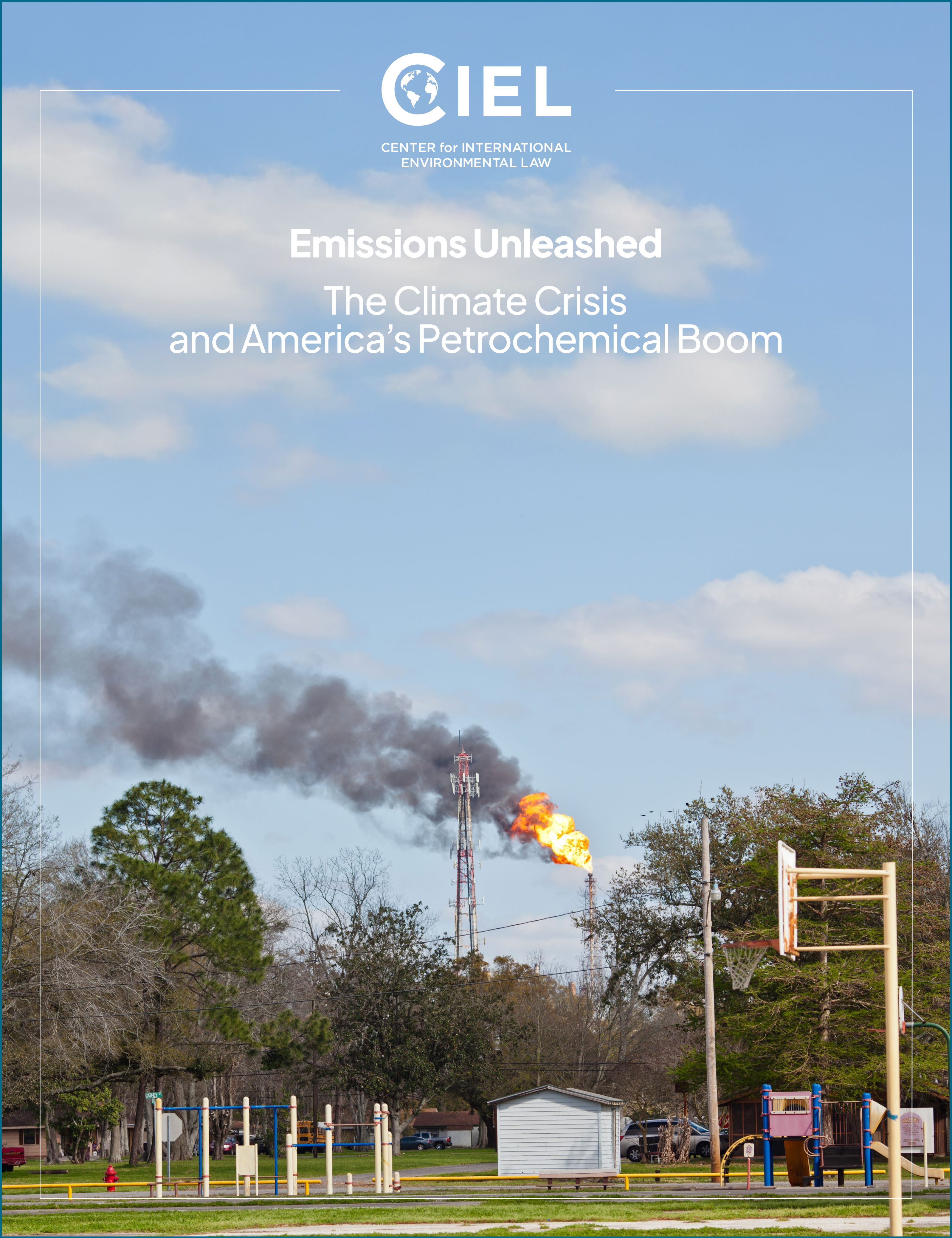
CENTER for INTERNATIONAL ENVIRONMENTAL LAW

Emissions Unleashed

The Climate Crisis and America's Petrochemical Boom



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Founded in 1989, the Center for International Environmental Law (CIEL) uses the power of law to protect the environment, promote human rights, and ensure a just and sustainable society. CIEL is dedicated to advocacy in the global public interest through legal counsel, policy research, analysis, education, training, and capacity building.

Acknowledgments

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Please send comments or questions to info@ciel.org to be sure of a reply.

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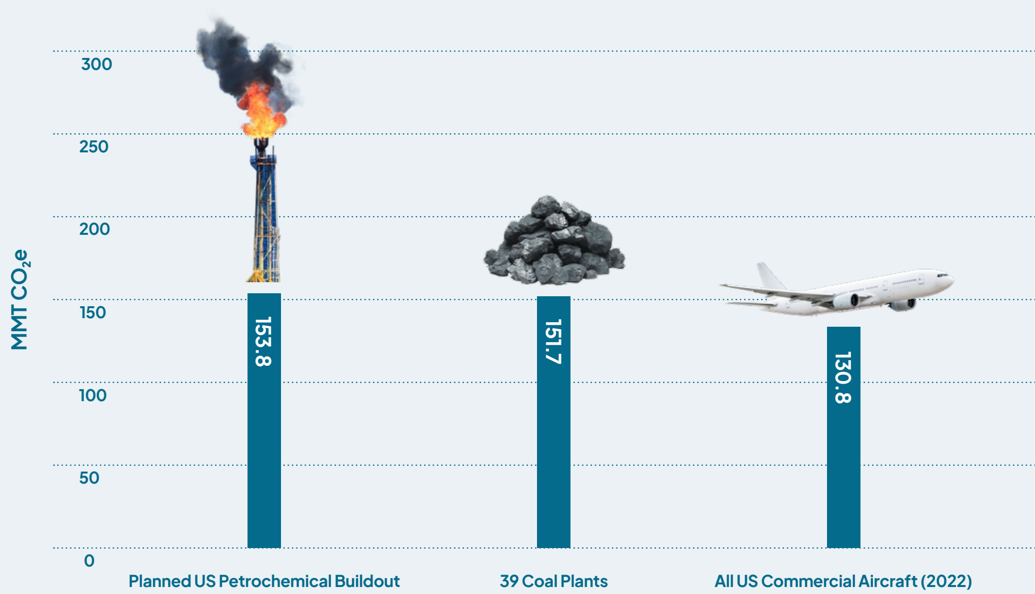
Key Findings

Petrochemicals are a significant and growing threat to the climate. The full supply chain of petrochemicals — from fossil fuel extraction and processing to petrochemical production and the use and disposal of petrochemicals — carries a large greenhouse gas (GHG) impact. Already, the petrochemicals sector in the United States contributes approximately 335 million metric tons (MMT) of carbon dioxide equivalent (CO_2e) per year, more than the annual emissions of Spain, or 5.2% of the United States' 6.3 billion metric tons of annual CO_2e emissions. The buildout of new petrochemical plants taking place in the United States over the next few years, analyzed in this report, could add an additional 153.8 MMT of annual CO_2e emissions, or an additional 2.4% of current US greenhouse gas emissions. The planned US petrochemical buildout could add 38% to current estimated emissions from US petrochemical production. Even if the emissions resulting from the production of intermediary chemicals are ignored, the production of final petrochemical products alone would generate 108.3 MMT CO_2e annually.

The planned petrochemical buildout would contribute more greenhouse gasses every year than all US commercial aircraft and is equivalent to nearly forty coal plants' annual GHG emissions.

Annual GHG Emissions from the US Petrochemical Buildout Are Equivalent to Adding Nearly Forty Coal Plants

Annual GHG emissions from the planned US petrochemical buildout would be equivalent to adding nearly forty coal power plants' annual emissions, and is more all US commercial aircraft annual emissions.

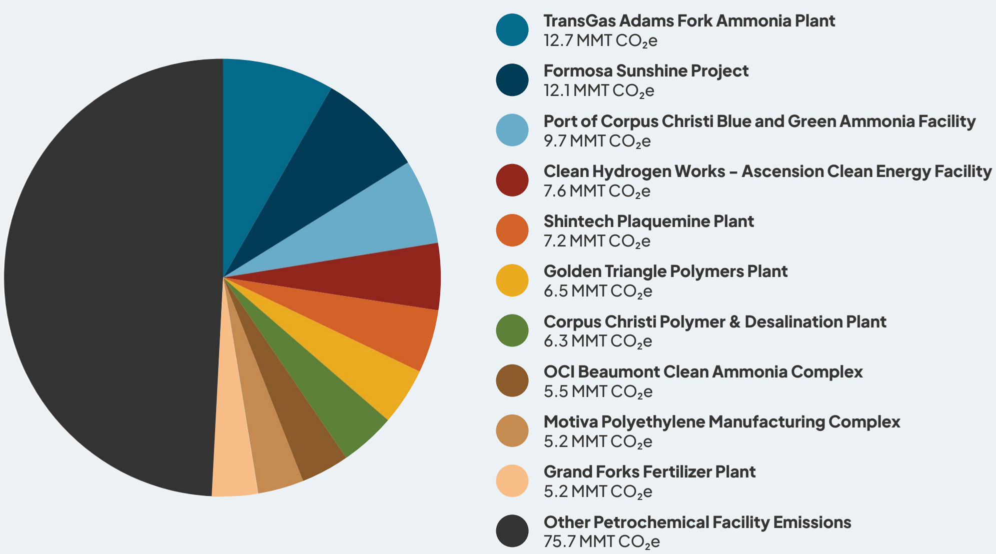


Source: CIEL analysis, Inventory of US Greenhouse Gas Emissions and Sinks: 1990–2022 US Environmental Protection Agency (EPA), emissions from jet fuel consumed by domestic operations of commercial aircraft.

Petrochemical megaprojects are driving the increase in production and pollution. Though there are more than one hundred petrochemical expansion projects planned and more than seventy in our analysis, just a handful of projects comprise the majority of new production and associated emissions. **Just ten megaprojects comprise half of the potential emissions identified in our analysis, while the largest twenty facilities make up three-quarters of the potential emissions.** The investment in and permitting of just a handful of petrochemical projects will have a profound impact on US greenhouse gas emissions and the ability of the US and the world to meet climate targets.

The Majority of Petrochemical Emissions Will Come from A Handful of Megaprojects

The ten largest projects make up more than half of potential GHG emissions from the US petrochemical buildout.



Source: CIEL analysis

The biggest slice of new emissions will come from ammonia production. Emissions from proposed ammonia production — not including fertilizer made from ammonia — make up more than a third of the projected new emissions. Proposals for new petrochemical projects include an additional 54.5 MMT of new production capacity, nearly quadruple current US ammonia production.[1] While 88% of US ammonia production is currently used to make fertilizers, this new buildout appears to be premised on the potential new use of the chemical as a shipping fuel and as a way to transport hydrogen.

Though couched as part of the climate solution, this fossil-fuel-based buildout moves us further from our climate goals, locking in fossil-based emissions for decades to come. The massive expansion of fossil-based ammonia production appears premised on its purported ability to act as a 'low-carbon' shipping fuel or as a way of transporting hydrogen, despite the significant greenhouse gas emissions from its production (and potentially its use). Despite the hype around using 'green ammonia,' made using renewable electricity, we find that up to 95% of the planned US ammonia production capacity would be based on methane (fossil gas). Thirty-two projects — all but one of which will manufacture ammonia or ammonia-based fertilizer — claim that they will use carbon capture and storage (CCS) to mitigate carbon emissions. These projects stand to collect hefty subsidies handed out for CCS and hydrogen production, facilitating a potentially massive buildout of fossil-fuel-dependent production. The plastics industry is also attempting to position plastic as a climate-friendly material necessary for the energy transition.

Carbon capture and storage has been a demonstrable failure. Our analysis demonstrates that even if CCS projects operated at the unrealistic levels of efficacy that proponents claim, carbon capture and storage systems could only be applied to around 60% of the life-cycle emissions from the facilities for which they are proposed. The truth is CCS has a track record of underperformance and outright failure and will likely capture far less than proponents claim. Moreover, CCS cannot capture the vast amount of upstream emissions from fossil fuel extraction and refining, nor the downstream emissions from petrochemical product use and disposal, which also account for a large portion of their life-cycle emissions. **Rather than act as a climate solution, carbon capture and storage effectively enable the expansion of petrochemical facilities that threaten to lock in fossil fuel production, greenhouse gas emissions, and climate destruction for decades.**

The true climate impact of petrochemicals is even worse than the numbers tell us. A combination of transparency gaps, data gaps, and knowledge gaps suggests that the true climate impact of US-based petrochemical production and use is far greater than our analysis found. Production estimates were only available for 74 of 118 proposed facilities, meaning around a third of the proposed petrochemical buildout could not be covered in our analysis. Additionally, poor official reporting and recording of methane emissions results in an undercount of the emissions impact of fossil fuel production and methane use in the industry, especially in ammonia and fertilizer production where methane is a key feedstock. Finally, unknowns about how plastic interferes with the global carbon cycle and how ammonia as a fuel will generate additional nitrous oxide emissions mask the ultimate potential impact of these products.

Our estimate of potential GHG emissions from the buildout is two-and-a-half times higher than the estimates provided by project promoters during permitting processes, which totaled 55.7MMT CO_2e per year.

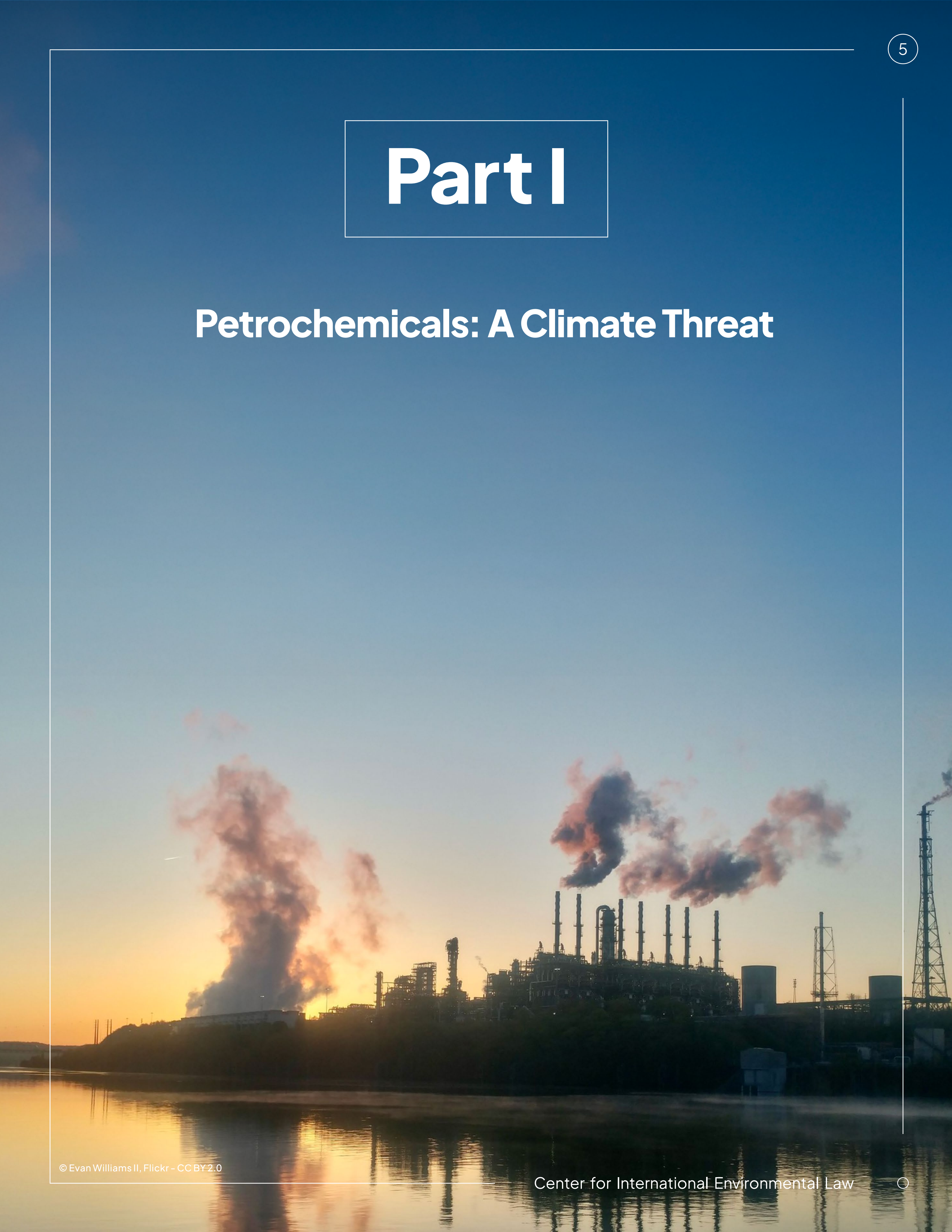
Plastics projects are being held up. Many of the projects currently on hold, not being developed but not yet canceled, are plastic production facilities. **Notably, nearly 60% of planned plastic production, calculated on the basis of potential emissions, is on hold, showing that a combination of local opposition and market forces is beginning to constrain the expansion of plastic production.**[2]

The delay in so many massive petrochemical production projects suggests that **investors already perceive significant risks around these petrochemical projects, especially around plastic,** and that the tide could turn against this massive quantity of new production.

Beyond the climate crisis, this petrochemical buildout will exacerbate environmental injustice. The petrochemical industry already drives great environmental injustice, with its pollution in the United States concentrated in low-income communities and communities of color, especially in the Gulf South and Appalachia. **The overwhelming majority of proposed projects, including nearly all the petrochemical megaprojects, are proposed within 'officially disadvantaged communities' that already experience impacts that include poor air and water quality and health impacts due to the high concentration of industrialized plants within their vicinity.**[3] This petrochemical buildout would add large amounts of new toxic pollution to these overburdened communities, exacerbating deep-seated environmental injustice.

Part I

Petrochemicals: A Climate Threat



Introduction

The petrochemicals sector is a major yet often overlooked source of greenhouse gasses that is poised for rapid expansion. As direct fossil fuel use for electricity, heat, and transportation is phased out, the increased use of fossil fuels as feedstocks for chemical production and alternative fuels guarantees to undermine climate progress in other sectors.

Most concerningly, support for expanded chemical production is enabled in large part by a misunderstanding of petrochemicals' true climate impacts. Plastics and fertilizers are often pitched as part of the climate solution when, in fact, they contribute massively to greenhouse gasses in the atmosphere.[4] Moreover, fossil fuel interests are attempting to launder their products — and emissions — through a new set of hydrogen-based fuels under the guise of climate action when the true climate cost of these fuels may be greater than the fossil fuels from which they are derived.[5] A large component of the current expansion is premised on federal subsidies, specifically climate subsidies.[6] If built, these petrochemical facilities will generate huge greenhouse gas emissions and lock in fossil fuel production for decades. This petrochemical buildout will continue a trend of heavily subsidized new facilities seizing on the US fracking boom.[7]

Petrochemicals, generally, are chemical products made from fossil fuels (oil, gas, and coal) used primarily for purposes other than energy. Common petrochemicals include plastics, synthetic nitrogen fertilizers, and methanol, but include other chemicals such as adhesives, explosives, synthetic rubbers, and paints.[8]

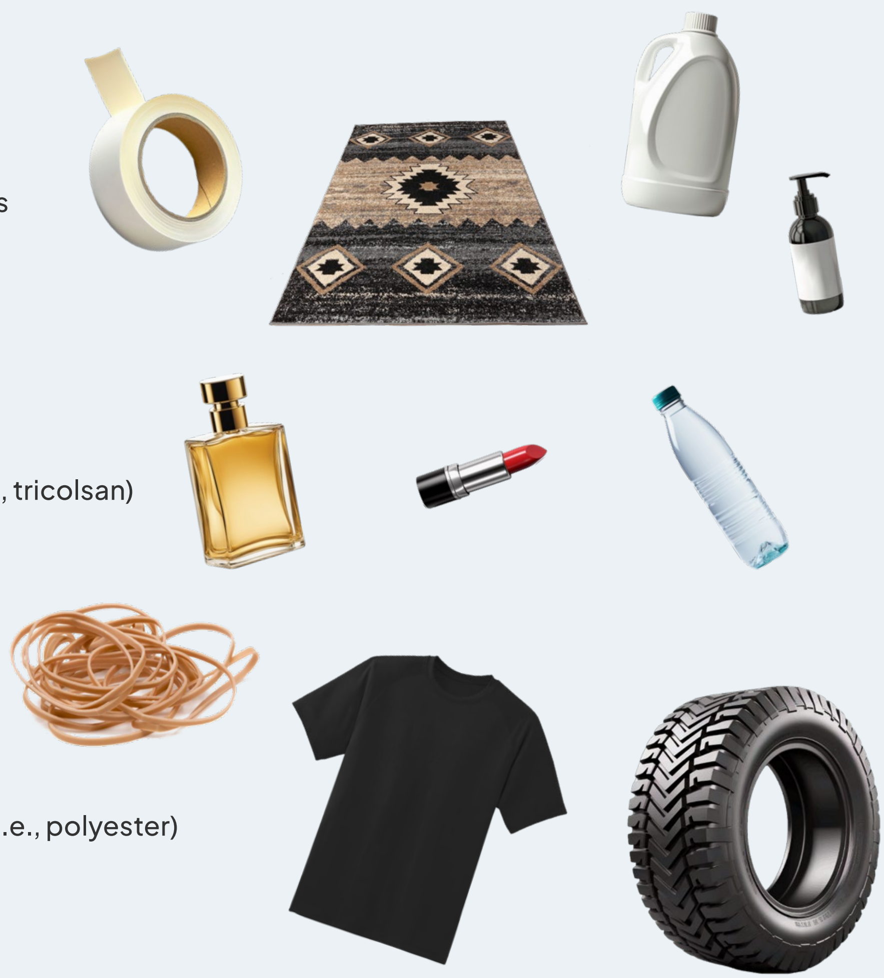
The International Energy Agency (IEA) has projected that petrochemicals will become the largest driver of global oil demand. They are set to account for more than a third of the growth in oil demand up to 2030 and nearly half of demand growth up to 2050 — ahead of trucks, aviation, and shipping. Petrochemicals are also poised to consume an additional 56 billion cubic meters of natural gas by 2030, equivalent to about half of Canada's total gas consumption today.[9]

At present, approximately 15% of global oil demand comes from petrochemicals, 8% of global gas is used for petrochemical production, and around 1% of coal is used for petrochemical production.[10]

Products Derived from Fossil Fuels that Aren't Fuel

Everyday household items made with petrochemicals:

- Adhesives
- Carpets
- Detergents & Shampoos
- Dyes
- Fertilizers
- Flooring
- Fragrance & Perfume
- Furniture
- Makeup (methanol, DEA, tricolsan)
- Medicines
- Neoprene (wetsuits)
- Pesticides
- Plastic
- Resins
- Rubber
- Synthetic textile fibers (i.e., polyester)
- Tires



Petrochemicals and Climate

Because petrochemicals represent the overlap between the fossil fuel and industrial sectors, the unique aspects of petrochemicals and their relationship to the climate crisis are frequently overlooked. Unlike other fossil fuel products, petrochemicals are not usually burned during their use phase. As such, they are distinct from products like gasoline (petrol) used to power cars and trucks, methane (natural or fossil gas) used to heat homes and buildings, or coal used to drive steam turbines in power plants. Petrochemicals are often overlooked in discussions relating to the 'energy transition' and the shift to renewable energy and are instead included in discussions of industrial decarbonization alongside industries like steel and cement.

Like other polluting industries, petrochemicals rely on fossil fuels for energy. However, unlike other emitting industries, the petrochemical sector's climate impacts don't end there. There are a few key factors that raise the petrochemical's sector climate-wrecking profile compared to other industries of concern. **Most fundamentally, petrochemicals are made from fossil fuels themselves, making them fundamentally inseparable from the primary driver of the climate crisis.**

Most fundamentally, **petrochemicals are made from fossil fuels themselves,** making them *fundamentally* inseparable from the **primary driver** of the climate crisis.

Additionally, because of the chemical nature of many petrochemical products, they produce significant greenhouse gas emissions even after their use. Plastics are often burned after their use, adding yet another layer of carbon dioxide (CO_2) emissions.[11] Moreover, as will be discussed at greater length below, plastics may also be interfering with the global carbon cycle.[12]

Synthetic nitrogen fertilizers, one of the most common categories of petrochemicals, also produce significant greenhouse gas emissions in their 'use phase' as they are applied to soil. The overapplication of nitrogen to soils leads to the direct and indirect creation of nitrous oxide, the third most important greenhouse gas and one which is 273 times stronger than carbon dioxide.[13] Moreover, because many fertilizers are made with carbon dioxide as a component, they release that carbon dioxide when applied to the field.[14] Ultimately, these field emissions have been observed to have an even greater greenhouse gas impact than the production of fertilizers themselves.[15]

Similar to sectors such as cement and steel, petrochemicals produce significant carbon emissions during production. It is their upstream connection to fossil fuels and the downstream greenhouse gas emissions from their use and disposal that make petrochemicals even more concerning than many other sectors.

Emissions from the US and Global Petrochemicals Sector

The emissions from the US petrochemicals sector are vast. According to figures reported by the US Environmental Protection Agency (EPA), the petrochemical sector emits approximately 157 MMT of CO_2e per year.[16] The EPA reports additional downstream emissions from plastic incineration (12.7 MMT CO_2e), urea hydrolysis (5.3 MMT), and direct N_2O emissions from fertilizer application (62 MMT CO_2e), for a total of 80 MMT CO_2e from downstream petrochemical use and disposal.[17]

Altogether, the EPA estimate of emissions from the production and use of petrochemicals amounts to 237 MMT CO_2e per year. This estimate excludes the upstream production and processing of fossil fuels into petrochemical feedstocks and thus significantly undercounts the actual emissions impact of the sector.

Independent analyses suggest emissions are higher than EPA estimates. A 2022 report from the Rocky Mountain Institute (RMI) found the US petrochemical industry — again excluding upstream emissions — emitted an estimated 172 MMT CO_2e.[18] C-THRU, whose published emissions factors are used in the analysis in this report, estimates US petrochemical emissions, including upstream emissions, at 255 MMT CO_2e (± 91) in 2023.[19]

Using C-THRU's estimate for emissions up to the point products leave a facility (cradle to gate) and EPA's estimated downstream emissions, current emissions from the life cycle of petrochemicals, not accounting for trade, can be estimated at approximately 335 MMT CO_2e. This represents approximately 5.2% of the United States' 6,343 MMT of CO_2e emissions in 2022, equal to emissions from 80 million passenger cars.[20]

The petrochemicals sector has a similar emissions profile globally. RMI's report estimated 2019 global petrochemical industry CO_2e emissions at 1.6 billion metric tons worldwide, accounting for 3% of global emissions just from the manufacturing phase. Cullen et al. of the C-THRU project estimate global petrochemical emissions, including manufacturing and upstream emissions, at 1.9 billion metric tons CO_2e 4 (± 0.6) in 2020.[21] This puts US petrochemical emissions at around 13% of global petrochemical emissions according to C-THRU's estimate or 10% according to RMI's.

Estimates of emissions from plastics and fertilizers, when full supply chains are taken into account, provide insight into the full climate impact of petrochemicals. A recent study by Lawrence Berkeley National Laboratory calculated emissions from plastic production alone — including upstream fossil fuel extraction and processing, though excluding downstream disposal and incineration — at 2.24 billion metric tons, or 5.3% of global emissions.[22] A study of emissions from nitrogen fertilizer production and use estimated 1.13 billion metric tons of annual emissions, accounting for 2.1% of global emissions.[23] Combined, these two estimates suggest that just plastics and fertilizers — the bulk but certainly not the entirety of petrochemicals — contribute 7.4% of global greenhouse gas emissions. Another estimate from Lund University, which excluded downstream impacts, concludes that petrochemicals and the extraction and production processes that feed into them account for approximately 10% of global emissions.[24] It is clear the climate impact of petrochemicals is vast — and growing.

Combined, these two estimates suggest that just *plastics* and *fertilizers* — the bulk but certainly not the entirety of petrochemicals — contribute **7.4% of global greenhouse gas emissions.**

Petrochemical Production Is a Growing Problem for the Climate

Petrochemicals are not only tied to fossil fuels and, therefore, are significant contributors to greenhouse gasses, but they are a rapidly growing problem. **To meet climate goals, all sectors of the economy must drastically reduce their emissions and transition away from reliance on fossil fuels. The petrochemicals sector is doing the exact opposite.**

To meet climate goals, **all sectors** of the economy must drastically reduce their emissions and transition **away from reliance on fossil fuels.** The petrochemicals sector is doing the *exact* opposite.

The aforementioned study from Lawrence Berkeley National Laboratory puts the scale of this potential impact in stark relief. The study examined the greenhouse gas impact of plastic production growth over the next three decades, accounting for emissions from upstream fossil fuel extraction and processing, associated chemical manufacturing, monomer and polymer production, and product molding and shaping. Looking at global plastics production only — not including the other petrochemicals — the authors found that **plastics production alone could account for a quarter of the global carbon budget available to limit warming to 1.5°C.** This estimate was based on a projection of future growth of plastic production at 2.5% per year.[25]

Our analysis does not project future growth for the petrochemical sector but rather examines the emissions for projects we know to be planned or already underway. In so doing, it highlights the imminent climate threat of existing plans for petrochemical expansion. If this trend of petrochemical expansion is not halted, it could be just the next chapter in a line of many petrochemical expansions to come in both the United States and globally. **Our analysis makes it clear: the petrochemicals sector is a present and growing threat to domestic — as well as global — efforts to confront the climate crisis.**

Our analysis also illustrates the absurdity of the notion that petrochemicals are critical climate solutions. The industry promotes fossil fuel-based ammonia and methanol as 'clean fuels' and 'climate solutions,' while they are, in fact, still highly polluting to produce and still result in additional emissions when burned. Nevertheless, fossil-based ammonia and methanol production is still supported with extraordinary subsidies from the federal government.[26] While the plastics industry touts its products as 'sustainable,' plastics account for some of the most heavily polluting proposed facilities, not to mention the concerning role plastic may play in disrupting the global carbon cycle.[27]

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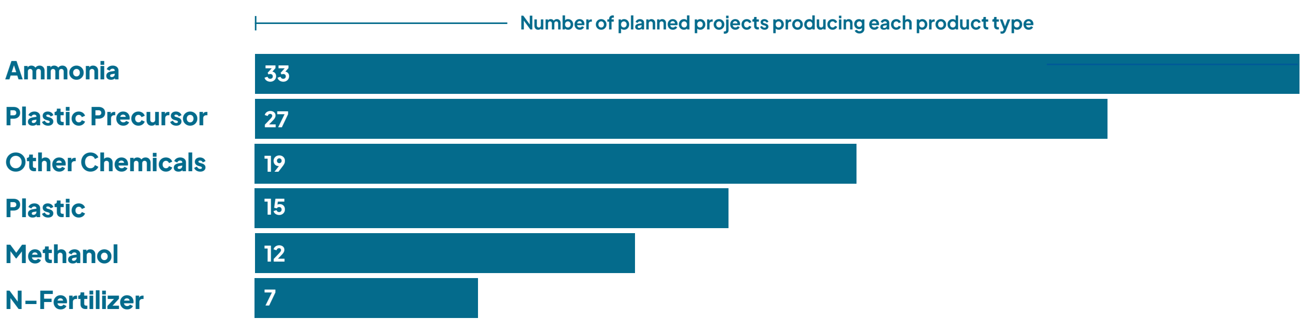
Where and What is the Petrochemical Buildout?

Between 2019 and 2024, the growth in petrochemical production capacity in North America, predominantly in the United States, was second only to China.[28] Our analysis tracks the continuing expansion of petrochemical facilities in the United States.

Using the Environmental Integrity Project's Oil and Gas Watch Database (Oil and Gas Watch Database), the Center for International Environmental Law (CIEL) identified 118 petrochemical projects that are either already under construction or planned to be built in the coming years. These projects include expansions of existing petrochemical facilities as well as the construction of entirely new facilities. Of these projects we were able to identify proposed production capacities for seventy-four projects, some of which plan to produce multiple products.

Planned Petrochemical Production Focuses on Ammonia and Plastics



Some projects will produce multiple types of products and are, therefore, counted more than once.
Projects without production capacity estimates are excluded.*

Source: CIEL analysis

Ammonia production is the most widespread type of new petrochemical project. 88% of US ammonia production is currently used to make synthetic fertilizers, with the remainder used for industrial purposes, including the production of plastics, synthetic fibers, and explosives.

While the scale of the ammonia buildout dwarfs existing production, many companies appear to be betting on ammonia as a 'fuel of the future' that could be used in power plants or to replace current shipping fuels.[29] For example, OCI, a company behind a proposed new ammonia facility in Beaumont, Texas, explained that "The US Gulf is a strategic location that allows the facility to serve both the US market and export clean ammonia as a hydrogen carrier to … Europe and Asia, as well as catering for expected significant demand from new applications including power and shipping fuels."[30]

Ammonia can be made with green hydrogen (hydrogen made from renewable electricity as the main feedstock). However, the vast majority of the ammonia projects in the planned buildout are basing their production on fossil fuels, calling into question claims that ammonia, in these cases, would provide a 'green' solution.

The Color Spectrum of Hydrogen and Ammonia

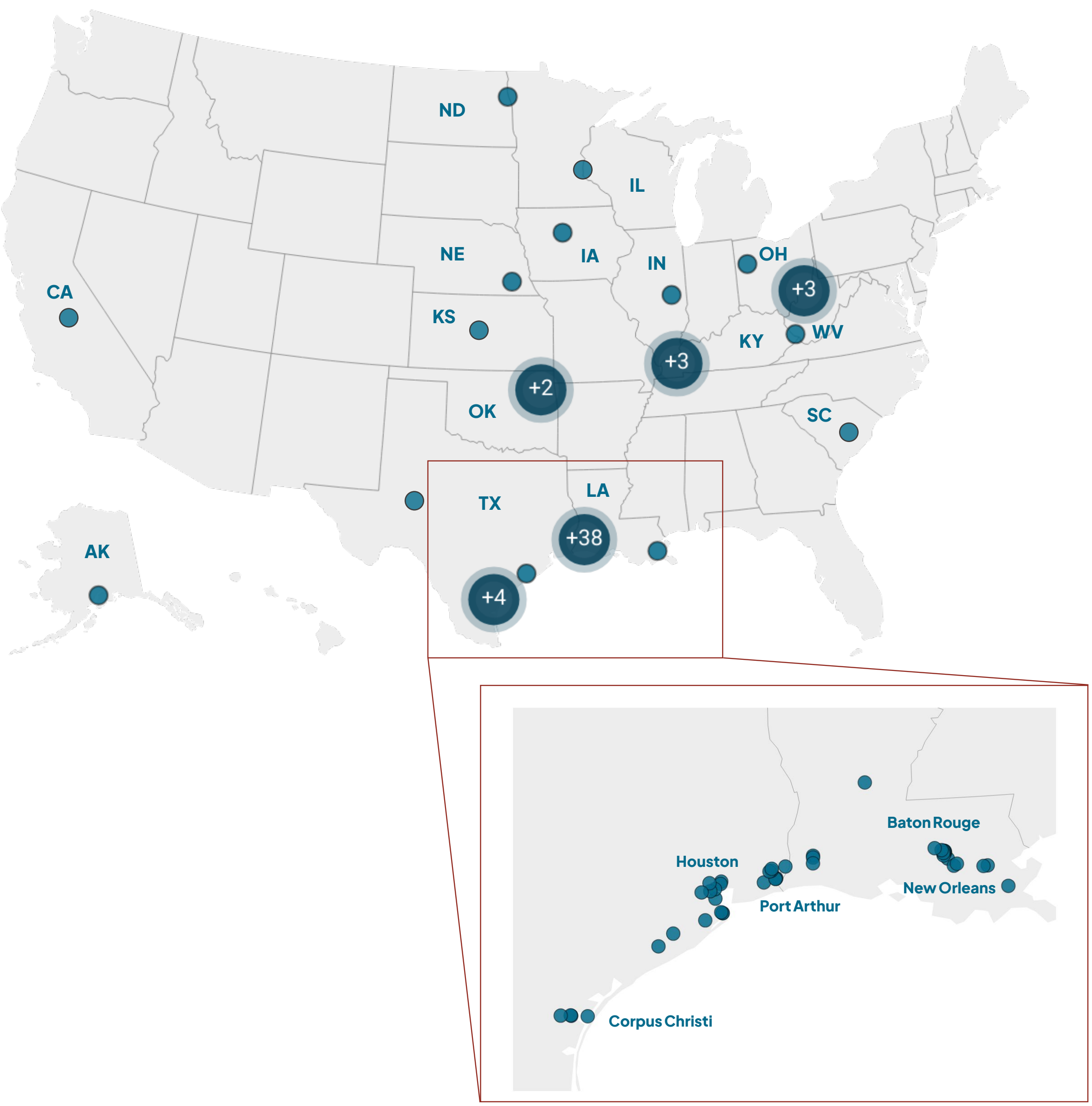
Gray Hydrogen	Blue Hydrogen	Green Hydrogen
Hydrogen made using methane (fossil) gas	Hydrogen made using methane (fossil) gas with some element of carbon capture	Hydrogen made through electrolysis using renewable energy

The ammonia color spectrum matches the type of hydrogen used as feedstock. A recent industry standard also suggests that all energy inputs for green ammonia, including through the energy-intensive Haber-Bosch process, should come from renewable sources, though it is unclear which project promoters will abide by this proposed standard.[31]

The planned petrochemical buildout closely mirrors the existing petrochemical footprint, with the majority concentrated on the Gulf Coast. Of the planned 118 projects, 87 are slated for Texas and Louisiana. Some of the largest planned projects are also in Appalachia. Communities in both regions already face the deadly impacts of the fossil fuel industry and petrochemical production. Take, for example, Louisiana's winding corridor of more than 200 fossil fuel and chemical facilities between New Orleans and Baton Rouge, often referred to as 'Cancer Alley' — where residents face some of America's highest cancer rates.[32] In St John the Baptist Parish, lifetime cancer rates are 800 times the US average, according to the Environmental Protection Agency.[33]

Proposed US Petrochemical Production is Concentrated in the Gulf Coast and Appalachia

Proposed projects are cited mostly in areas already heavily impacted by industrial pollution.



Source: CIEL analysis

Beyond its greenhouse gas emissions, petrochemical production also bears an enormous toxic footprint. Pollution from fossil fuel processing and chemical manufacturing burdens communities along the fenceline of production facilities, leading to extreme and deleterious health effects. Communities exposed to these toxins have higher rates of cancer, experience respiratory problems such as asthma, suffer reproductive harms, and more.[34]

Because petrochemical facilities cluster, detrimental impacts are compounded for people living in adjacent communities. In the United States, there are two extreme hotspots of petrochemical clustering and corresponding environmental injustice: the greater Houston region in Texas and the corridor between Baton Rouge and New Orleans in Louisiana. The former has some of the worst air quality in the nation,[35] while the latter is known as 'Cancer Alley' due to the extreme concentration of cancer risk in the eighty-five-mile stretch along the Mississippi River.[36] Notably, these communities are disproportionately communities of color or low-income communities, and the development of these clusters is a prime example of environmental racism in facility siting, permitting, and operation. The disparities are so severe that in 2021, a group of UN human rights experts raised an alarm about the failure to protect human rights and systemic environmental racism in Cancer Alley.[37]

Already, fossil fuel-linked air pollution is responsible for one in five deaths globally.[38] As climate change accelerates, the impacts of heat, smoke, extreme weather, and disease will combine and compound the impacts of toxic emissions, increasing the health burden on affected communities.[39]

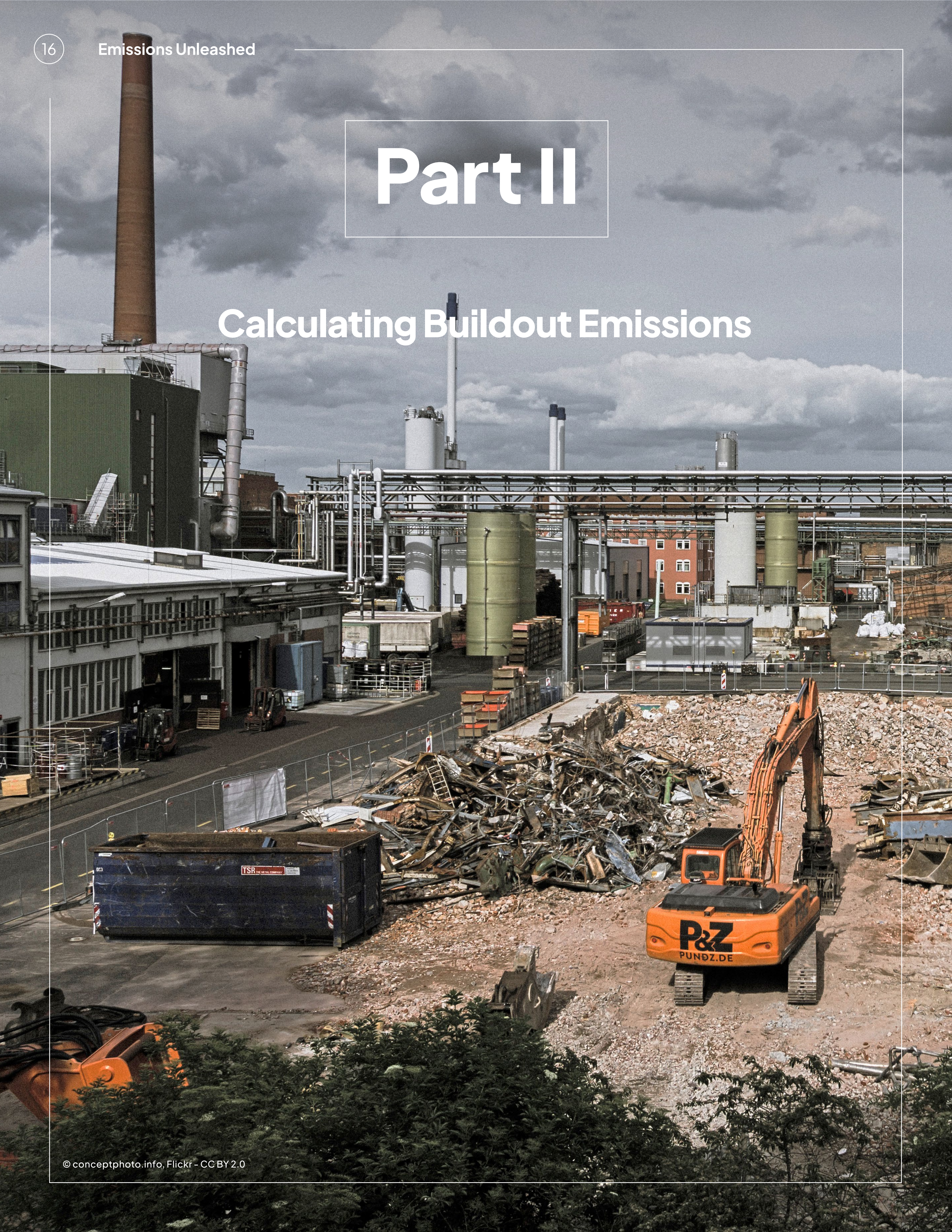
Top 10 Polluting Facilities

	Facility / Company	State	Products	Projected emissions (MMT)
1	TransGas Adams Fork Ammonia Plant / Adams Fork Energy, TransGas Development Systems LLC	WV	Ammonia	12.7
2	Formosa Sunshine Project / FG LA, LLC	LA	HDPE, LDPE, Polypropylene, Ethylene glycol	12.1
3	Port of Corpus Christi Blue and Green Ammonia Facility / Lotte Chemical, Mitsubishi Chemical America Inc, RWE	TX	Ammonia	9.7
4	Clean Hydrogen Works - Ascension Clean Energy Facility / Clean Hydrogen Works LA-1 LLC, Denbury Carbon Solutions, LLC, Hafnia, Mitsui O.S.K. Lines	LA	Ammonia	7.6
5	Shintech Plaquemine Plant / Shintech Louisiana, LLC	LA	Ethylene, Vinyl Chloride Monomer	7.2
6	Golden Triangle Polymers Plant / Chevron Phillips Chemical Company LP, Golden Triangle Polymers Company LLC	TX	Ethylene, HDPE	6.5
7	Corpus Christi Polymer & Desalination Plant / Corpus Christi Polymers LLC	TX	PET resins, PTA (purified terephthalic acid)	6.3
8	OCI Beaumont Clean Ammonia Complex / OCI Clean Ammonia LLC	TX	Ammonia, Urea, Nitric Acid	5.5
9	Motiva Polyethylene Manufacturing Complex / Motiva Chemicals LLC	TX	HDPE, LLPDE	5.2
10	Grand Forks Fertilizer Plant / Northern Plains Nitrogen, LLP	ND	Urea, Urea Ammonium Nitrate, Ammonium Nitrate, Ammonium Thiosulfate, Ammonia	5.2

- **West Virginia**
- **Louisiana**
- **Texas**
- **North Dakota**

Part II

Calculating Buildout Emissions



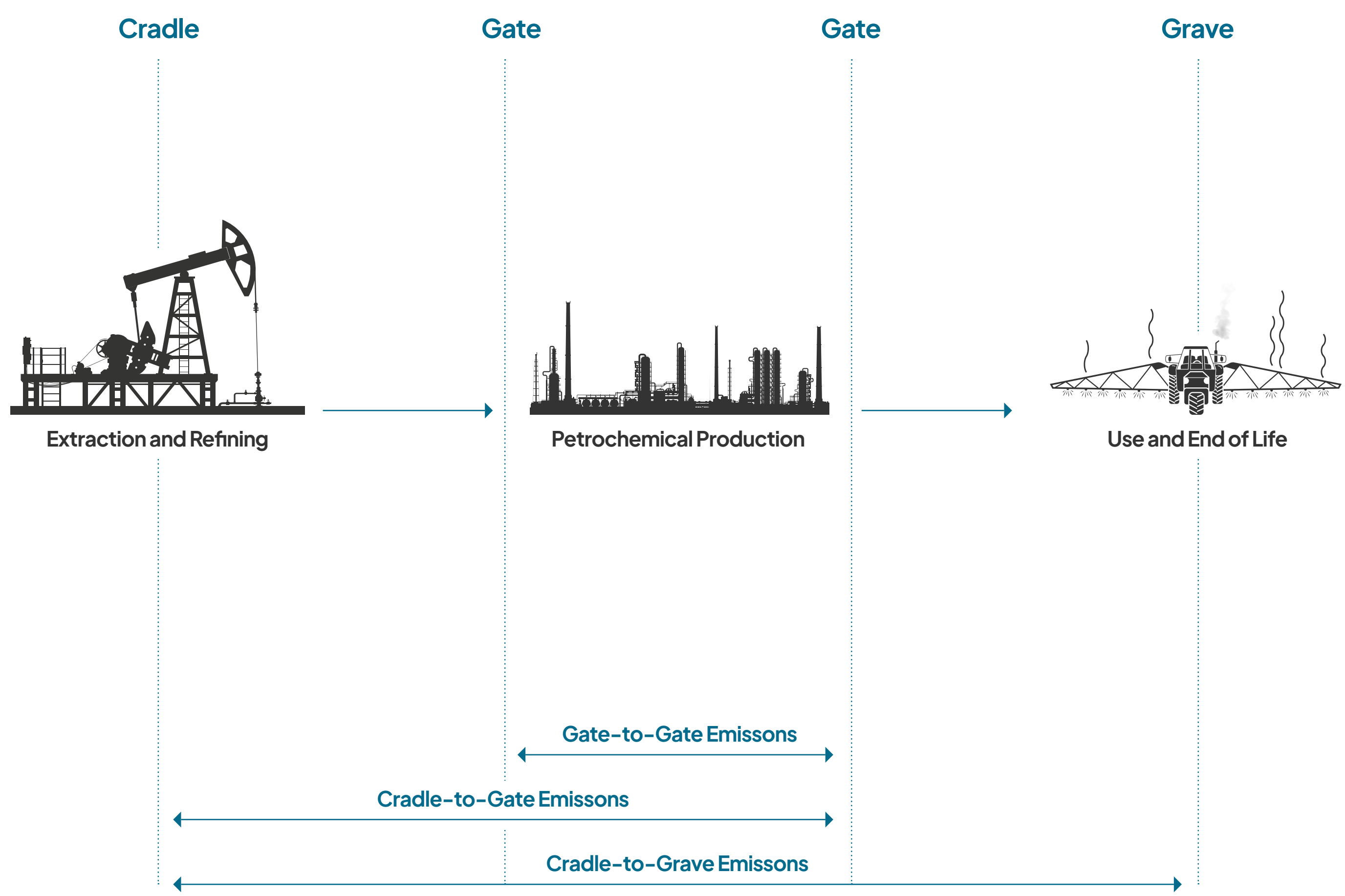
Methodology

Overview

In this analysis we set out to quantify the potential emissions from new petrochemical production facilities, including emissions from all major phases of petrochemical products' life cycle.

Data compiled by the Environmental Integrity Project in the Oil and Gas Watch database allowed us to identify relevant planned petrochemical projects. To estimate the scale of potential petrochemical production, we collected production capacity figures for proposed petrochemical plants in the United States. We then used emissions factors published by the C-THRU project to estimate the emissions that this level of production would produce at the facility, known as gate-to-gate emissions. These emissions factors also allowed us to calculate 'cradle-to-gate' emissions, which include both the emissions at a facility as well as the upstream emissions from oil and gas extraction and other energy inputs. We added estimates for the potential impacts of the implementation of carbon capture systems, noting their track record of failing to live up to performance claims. We supplemented these figures with estimates of emissions from plastic incineration as well as the on-field emissions of fertilizers to arrive at 'cradle-to-grave' emissions, which cover the emissions over the full life cycle of petrochemical products.

Greenhouse Gas Emissions are Generated at Each Step of the Petrochemical Supply Chain



Source: CIEL analysis

Estimates of greenhouse gas emissions from large stationary sources like petrochemical facilities are collected by the US Environmental Protection Agency under the Clean Air Act.[40] CIEL and others have used these estimates to analyze the impact of the US petrochemicals industry on climate change in the past, for example, in CIEL and partners' 2019 report *Plastic and Climate: The Hidden Costs of a Plastic Planet*.[41]

GHG emissions are also required to be estimated and disclosed as part of the permitting process for new projects that will cause pollution over certain thresholds, including petrochemical projects.[42] However, at any given time, many proposed petrochemical projects will not have disclosed these official estimates, for example, if they have not yet applied for the relevant permits.

Using the Environmental Integrity Project's Oil and Gas Watch Database, we identified 118 petrochemical projects that are either under construction or in the planning phase. Projects were included from the announced, commissioning, pre-construction, under construction, and on-hold categories, as classified in the database.[43] This excludes currently operating or partially operating projects as well as canceled projects. Some projects are planned as entirely new facilities, while others are additions within an existing facility. 'On-hold' projects are stalled or delayed and not yet operational. The 'hold' may be due to disputes over permitting, local opposition, litigation, or companies waiting for more favorable economic conditions. The list of projects and their status was last accessed on May 15, 2024, and these findings, therefore, reflect the classification of projects at that time.

We focused our analysis on the growth in petrochemicals, excluding refineries and the first stage of refining operations, which is sometimes, but not always, included as part of the petrochemical sector but also supplies other sectors. This means that we excluded refineries, natural gas liquids fractionation plants, condensate splitters, and natural gas liquids storage hubs. We also excluded synthetic fuel production, for example, 'sustainable aviation fuel,' which for this report is classified as a fuel product rather than a petrochemical. We did not include chemical recycling facilities. We relied on the Oil and Gas Watch database for their classification of projects.

We excluded hydrogen and syngas production facilities that do not make further products. We do include ammonia, fertilizer, methanol, and other projects that may include hydrogen production as feedstock for their final products. We did not include separate emissions estimates for any hydrogen production that is not used as a feedstock for their final products.

Our selection of projects includes ethylene crackers, propylene plants, ammonia plants, methanol plants, synthetic fertilizer manufacturing, plastic resin manufacturing plants, and the manufacture of other petrochemicals. A total of 118 projects fit our criteria.

Production Capacity

Of the 118 projects, only forty-three disclosed potential GHG emissions estimates. No information on potential GHG emissions was disclosed for the other seventy-five — nearly two-thirds of these potential new petrochemical projects. Rather than rely on disclosed GHG estimates, we collected information on potential production capacity for as many projects as possible in an effort to independently estimate their potential emissions.

We sourced proposed production capacity estimates from permitting documents, news coverage, press releases, and other materials aimed at investors. Some of this crucial information is already collated in the Oil and Gas Watch Database.[44] We were able to identify production capacity estimates for seventy-four projects, almost two-thirds of the proposed US petrochemical projects. Of these projects, we were able to determine potential emissions estimates for seventy-one projects. The three remaining projects will produce materials that don't have a clear, reliable emissions factor from which to draw.[45]

Ten projects listed their production capacity in the quantity of product made per day. However, petrochemical facilities do not typically operate 365 days a year, with their 'capacity utilization' instead allowing for maintenance and unplanned downtime. Different types of plants will have different average capacity utilization; for example, US plastics material and resin manufacturing facilities have operated at an average capacity utilization of 86.7% since 2015. Chemical manufacturing facilities have operated at an average capacity factor of 74.7% over the same period.[46] Newer facilities are also more likely to operate at higher utilization factors as they may need less planned maintenance. Therefore, we applied an 85% capacity utilization factor for the facilities that only list their capacity per day. Where annual production capacity was provided, we used this figure.

Emissions Factors

An emissions factor is a coefficient that quantifies the emissions of a gas per unit of activity.[47] In the context of petrochemicals, emissions factors provide a figure for greenhouse gas emissions per tonne of a product made. For our analysis, we combined the proposed production capacity with emissions factors to determine the GHG emissions per tonne of product produced. The C-THRU project developed and published the emissions factors, providing gate-to-gate and cradle-to-gate emissions estimates for each product identified.

Gate-to-gate emissions account for direct energy use and direct process emissions, essentially only the emissions on-site at a facility. Cradle-to-gate emissions, however, include all gate-to-gate emissions as well as emissions resulting from the feedstock used and from indirect energy use, for example, from power generated outside of a facility.

C-THRU is an academic project seeking to provide "carbon clarity in the petrochemical supply chain" and minimize GHG emissions, in part by delivering the world's most comprehensive, reliable, and transparent account of current and future emissions for the global petrochemical sector. The C-THRU methodology is summarized below but is explored in more detail in the 2024 paper "Reducing uncertainties in greenhouse gas emissions from chemical production" by Cullen et al.[48]

C-THRU has created a methodology for life-cycle emissions analysis to generate emissions factors for 2,043 petrochemical production processes. In compiling the emissions factors C-THRU relies on 'process recipes' from the IHS Process Economic Program Yearbook matched to likely feedstock and products identified.[49] C-THRU's methodology collects data for the different elements of emissions factors from a range of sources:

- Upstream feedstock emissions used in C-THRU's emissions factors are based on the Ecoinvent life-cycle emissions database.[50]
- 'Direct process' emissions come from the chemical reactions involved in the production process. These are based on equations obtained from the IPCC.
- For this analysis, a US grid-specific energy intensity of 0.45 kg CO_2e/kWh, based on Ecoinvent and IEA figures for 2020, was used in calculating indirect energy use emissions from energy generation, including off-site electricity generation.
- Direct-energy-use emissions include CO_2e emissions from the on-site combustion of fuels to generate heat. The GREET database from the US Department of Energy is used for US-specific figures. The GREET database assumes a methane leakage rate of 0.9%.[51]
    - Note: Actual methane leakage rates are difficult to measure, though they heavily impact the assumed emissions from the US petrochemical industry, which relies heavily on methane gas. An analysis of the results of all peer-reviewed estimates of methane emissions in gas fields in the US up to 2021 found that the mean emission rate, weighted by the volume of production in the different gas fields studied, is 2.6%.[52] A recent study of nearly 1 million aerial survey measurements from the US oil and gas system suggested that the average methane leakage rate was 2.95% — three times higher than the GREET figure used — which is, therefore, likely to be very conservative.[53]
- Chemical production processes often create multiple products in any given chemical reaction; these are known as co-products. To avoid double counting emissions, the emissions from a reaction are split and allocated between the different co-products on the basis of their respective masses in what is known as a mass balance system.

All emissions are expressed in CO_2e totals. Global Warming Potentials (GWP) over 100 years are used in our figures, matching C-THRU's methodology and data availability.

However, the use of a one-hundred-year GWP as the default option has been challenged in recent years as the role of methane in climate change has become better understood. According to the IPCC, since 1900, methane has caused 0.5°C of global warming compared to 0.75°C in warming caused by carbon dioxide.[54]

The one-hundred-year GWP of methane is calculated as 29.8 times more powerful than carbon dioxide, but its twenty-year GWP gives a much higher figure: 82.5 times more powerful.[55] The use of a 100-year GWP arguably does not reflect the level of warming, which is much better illustrated using a twenty-year GWP. This is reflected in the growing use of a twenty-year GWP in climate targets enshrined in law in New York and Maryland.[56]

The choice of twenty- or one-hundred-year GWP is especially relevant given the high methane usage in the US petrochemical sector. It should be noted that if we were to reflect results using a twenty-year GWP, the result would likely be far higher given the near-term impact of methane emissions. This methane impact would be especially obvious if a more accurate methane leakage rate was used rather than the 0.9% rate assumed in the GREET database.

An analysis by IEEFA found that hydrogen production modeled with a one-hundred-year GWP and with an assumed 1% methane leakage rate gives a carbon intensity of 13.6 kg of CO_2 per kg of hydrogen, but using a twenty-year GWP and a 4% methane leakage rate, this increases to 22.6 kg of CO_2 per kg of hydrogen (both using the standard steam methane reforming process). The variation between the two sets of assumptions is even more stark when carbon capture systems are included. With an assumed capture rate of 70%, IEEFA found that in the one-hundred-year GWP and 1% methane leak rate, emissions were 8 kg of CO_2 per kg of hydrogen, but with the twenty-year GWP and 4% methane leak scenario, this increased to 18 kg of CO_2 per kg of hydrogen.[57]

Another recent study, which looked specifically at green and blue ammonia production emissions, found that even with optimistic modeling assumptions and a one-hundred-year GWP-based comparison, methane leakage rates would have to be below 0.2% to compete with green ammonia. The study further found that the climate change impacts of blue ammonia double at the global average leakage rate of 2.2% and increase seven-fold at a higher methane leakage rate of 9%.[58]

When using full life-cycle or cradle-to-grave figures, if potential products are part of the same supply chain, there is a risk of double counting emissions as some intermediary products may be used as feedstock in another project in our list. This does not apply to the final products for which we have emissions estimates, such as plastics and fertilizers. New petrochemical projects may, though, be aimed at maximizing existing facilities' production by removing bottlenecks or reducing costs, as opposed to only feeding other new facilities, in which case using the cradle-to-gate emissions better reflects increased emissions from increased total output.

It should be noted that some of the highest proportions of emissions in our analysis come from ammonia and methanol production. Ammonia and methanol would typically be treated as primary chemicals and made to be used in other industrial applications such as ammonia production or plastics. However, ammonia and methanol are increasingly being viewed as potential fuels, particularly for shipping.[59] Considering the use of ammonia or methanol as a potential fuel means they should be treated as final products, though it is challenging to predict exactly what proportion of the potential ammonia production would go to fuel use. Given the difficulty of assessing where the potential projects sit in existing or new supply chains, their cradle-to-gate emissions have been applied.

We present a second figure in the findings section that reflects only the emissions from final products, which eliminates any possibility of double counting. For this analysis, we treat ammonia, methanol, plastics, and fertilizers as final products.

After applying C-THRU's emissions factors for gate-to-gate and cradle-to-gate emissions for each project, we applied carbon capture rates to the gate-to-gate emissions for each product included in a project. The reductions from these gate-to-gate emissions were also applied to the cradle-to-gate emissions. A sensitivity analysis was conducted to reflect, on the one hand, the wildly high carbon capture rates that project promoters advertise and, on the other hand, likely emissions should carbon capture plans fail — as history shows they often do. The capture rates we use both in our base scenario and in our sensitivity analysis are explained further below.

We further added use and end-of-life emissions for plastics and fertilizers as final products. Products not given use and end-of-life figures reflect the fact that they are likely to be used as intermediary chemicals for further products.

Use and End-of-Life Emissions

Petrochemicals create greenhouse gas emissions even after they leave a factory, and these should be accounted for in estimates of their life-cycle impacts. There is a broad set of potential emissions sources from use and end of life that this study does not estimate due to lack of available data, relative scale, or methodological concerns. Those potential end-of-life emissions are described below.

The two major sources of greenhouse gas emissions we have calculated for petrochemical uses and end-of-life emissions are the incineration of plastic and field emissions from fertilizers.

Emissions from Plastic Incineration

Incineration refers to the burning of plastic and may be deliberate or unintentional. Deliberate burning may include energy recovery, where plastic is used as a fuel for heat or power, or without energy recovery, where the plastic is burned as a waste management technique. Whatever the form of burning, the carbon that forms the spine of the plastic polymers is oxidized, and carbon dioxide is released.

For the purposes of this study, we used the proportion of plastic burned in US incinerators to generate an estimate of how much of the newly produced plastic would ultimately be burned. Though much of the plastic will likely be destined for export, US incineration rates are lower than the global average of 19% and do not include open burning of plastic waste.[60] As such, we believe our estimated incineration rate of 15.8% — the current US incineration rate for plastic waste — is likely conservative.[61]

Moreover, we estimated that 60% of produced plastic would end up as waste within a reasonably projectable timeframe. At present, in the US, for every 10 metric tons of plastic produced, around 6 metric tons of plastic waste is generated.[62] Again, this is less than the global average and is likely an underestimate.

Based on calculations from CIEL's 2019 *Plastic and Climate: The Hidden Costs of a Plastic Planet* (*Plastic and Climate*) report, we estimate approximately 2.9 metric tons of carbon dioxide emitted per tonne of plastic burned.[63]

Several sources of emissions from the downstream use and disposal of plastics are not considered in this analysis. In particular, emissions from transportation, conversion of plastics into products, and conventional recycling are excluded. Rates of incineration do not consider 'open burning' plastic incineration without energy recovery.

Emissions from so-called chemical or advanced recycling projects are also not considered. In addition to concerns around hazardous waste and pollution from such facilities, the technology has not proven to be a viable solution to plastic waste despite having interested researchers since the 1970s.[64] These projects also often act as waste-to-fuel projects and would contribute significant additional greenhouse gas emissions in their operation and in the combustion of the fuels produced.[65]

Emissions from Fertilizer Use

Fertilizer projects make up a significant proportion of the buildout. However, the manufacturing process of turning fossil fuels into fertilizers only makes up part of their emissions over their life cycle. The climate impacts of fertilizers are more widely explored in CIEL's 2022 report *Fossils, Fertilizers, and False Solutions*.[66]

When nitrogen fertilizer is applied to agricultural soils, it results in greenhouse gas emissions through several pathways. First, the application of nitrogen fertilizers leads to emissions of nitrous oxide (N_2O), a powerful greenhouse gas with 273 times the warming potential of carbon dioxide. N_2O is also created through two indirect pathways, as subsequent nitrogen products, particularly ammonia, are volatilized in soil and water. Finally, carbon dioxide used in the production of urea, the most common fertilizer, is re-released back into the atmosphere.[67]

There are multiple ways to estimate the emissions profile of fertilizer as applied in agriculture. Emissions depend on the amount, the crops being grown, the nature of the soil, and the climatic conditions. For the purposes of this study, we used empirical emissions estimates drawn from a comprehensive global study of greenhouse gas emissions from the production and use of nitrogen fertilizer.[68]

For the purposes of this analysis, we used greenhouse emission rates from fertilizer use in the United States. Greenhouse gas emissions from field application per tonne of applied nitrogen in the United States are lower than the global average, and this is, therefore, likely a conservative estimate as some US-made fertilizer will likely be exported.

Our analysis only considers emissions from known fertilizer products, not from ammonia. At present, 88% of current US ammonia production is used for fertilizer production, so it is likely that a fair amount of the proposed ammonia production would be destined for fertilizers. However, the scale of the proposed expansion in ammonia capacity is roughly four times the existing US capacity and is premised in large part on the (speculative) use of ammonia as a fuel. As such, we have chosen not to estimate the use emissions from ammonia and only calculated emissions for the production of urea, urea ammonium nitrate, and ammonium sulfate.

Petrochemicals' Interference with Carbon Cycles and Sinks

Petrochemical products may affect or already be affecting the climate in significant yet poorly understood ways. Overuse of nitrogen fertilizer can harm soil health and impede the ability of soil to absorb carbon.[69] In addition, plastics may affect global carbon cycles in ways that are increasingly facing scrutiny and scientific analysis. Though these impacts are not currently quantifiable, their potential impact must be considered in an analysis of petrochemicals' full climate impacts.

Plastics are potentially disturbing a key marine carbon sink mechanism. Phytoplankton and zooplankton, tiny organisms that form the base of marine food webs, also play a major role in the global carbon cycle. The oceans are responsible for absorbing nearly two-thirds of the carbon dioxide released since the beginning of the industrial era and remain a major carbon sink today. Most of that carbon stays at the surface of the ocean, but some makes its way down to the depths via the 'oceanic carbon pump.' This process involves phytoplankton drawing carbon in as they grow, and as they are eaten by zooplankton and then larger animals, the carbon that constitutes their structures is excreted or otherwise falls into the ocean depths, making room for more carbon at the surface.

Evidence increasingly suggests that microplastics are interfering with this key oceanic process. Microplastics have been found to interfere with respiration and reproduction in key planktons. Moreover, the buoyancy of many microplastics appears to be slowing the descent of carbonaceous material, trapping the carbon in the surface ocean for longer periods of time. Altogether, **microplastics may directly reduce the ability of the largest global carbon sinks to fulfill that function,** forcing more carbon dioxide to remain in the atmosphere and contributing to greater global warming.[70] We discussed the potential climate implications of these studies further in our 2019 report, *Plastic and Climate*.[71]

Of additional concern is the discovery that plastics release small amounts of greenhouse gasses, namely methane and ethylene, as they degrade in the environment. Such off-gassing is proportional to surface area, suggesting it will become an increasing source of greenhouse gas emissions as plastics accumulate in the environment.[72]

The overuse of nitrogen fertilizers also poses a danger to the climate. Nitrogen fertilizers, together with the pesticides they are often used alongside can degrade soil quality and reduce the ability of agricultural soils to hold onto carbon.[73] Global soils are another store for great stocks of carbon and represent both a significant source of carbon emissions due to current agricultural practices, as well as a significant potential sink. Nitrogen pollution also leads to eutrophication, a process that results in algal blooms, dead zones, and fish kills. The planetary boundary for biogeochemical flows, the cycling of nitrogen and phosphorus, is among the boundaries scientists say have been crossed, stemming directly from the extensive use of synthetic fertilizer.[74]

Carbon Capture and Storage

Carbon capture technology has repeatedly failed to live up to its claimed capabilities. A recent review by the Institute of Energy Economic and Financial Analysis (IEEFA) of sixteen projects revealed that, despite industry claims that a 95% capture rate is achievable, no existing project has consistently achieved a capture rate of more than 80%, and most have achieved far lower capture rates.[75]

Seventeen of the projects for which we obtained production data claimed they would apply carbon capture and storage (CCS) processes to either existing or new petrochemical production, sixteen of them aimed at producing ammonia and nitrogen fertilizers, and one at producing methanol.[76] Many of the projects included ambitious claims for potential carbon capture rates, either in percentage terms or in metric tons of carbon dioxide 'captured' per year.

Companies' claimed capture rates are not likely to take into account the emissions from the energy-intensive capture system itself, nor the upstream emissions that fuel the process. They also don't reflect the emissions and potential leakage during transportation and attempted storage of the carbon dioxide, if any is indeed stored at all, or its likely potential use in enhanced oil recovery. Globally, 73% of annual captured carbon is used for enhanced oil recovery.[77]

Growth in the number of planned ammonia and methanol plants equipped for carbon capture is likely reflective of the extremely generous subsidies for carbon capture and storage and hydrogen production through carbon capture and storage, referred to by their Internal Revenue Code sections 45Q and 45V, respectively.

In our base case, we applied a carbon capture rate based on data available on historical hydrogen projects. Only a small handful of projects are operating with carbon capture despite the technology being in operation for decades. For ammonia and methanol projects, carbon capture processes could be applied to the manufacturing of hydrogen, which is then synthesized into ammonia or methanol.[78] Therefore, we used hydrogen projects with carbon capture as our reference point for the assumed carbon capture figure. We applied this rate to the full gate-to-gate emissions as we do not have a breakdown of emissions between hydrogen production and the synthesis steps.

According to a review conducted by IEEFA in September 2023, there are only two commercial-scale hydrogen production facilities in the world that currently operate with CCS, capturing more than 1 MMT per year of CO_2. Project Quest in Alberta, operated by Shell, claims to have captured 68% of its CO_2, though it only appears to have achieved that level of performance if the emissions associated with the capture process itself are ignored. Air Products' Port Arthur hydrogen facility captured an average of less than 50% of the CO_2 generated by the hydrogen production process. Given that the facility did not capture any of the CO_2 released from the production of power to run the hydrogen production units and carbon capture system, the effective onsite CO_2 capture rate was well below 40% according to IEEFA's analysis.[79]

In a February 2024 article, a hydrogen analyst at the energy consultancy firm Wood Mackenzie succinctly explained, "capturing more than 60% of the carbon dioxide from hydrogen production is costly and has yet to be proven at scale."[80]

It should be noted that any claims of the efficacy of carbon capture should be treated with great caution given the technology's decades of overpromotion and under-delivery. Capture rates have been applied to gate-to-gate emissions, meaning they are applied to all direct energy use and direct emissions from the energy and chemical processes that occur onsite at a facility.

It should be noted that *any claims* of the efficacy of carbon capture should be **treated with great caution** given the technology's decades of **overpromotion** and **under-delivery.**

In the case of ammonia production, it is also likely that any carbon capture system would only cover the hydrogen production phase, not the energy-intensive Haber-Bosch process used to synthesize ammonia. This means that only a portion of emissions resulting from ammonia production would, in fact, be covered by any possible carbon capture process. As we do not have separate emissions estimates for the hydrogen production and synthesis steps or emissions from the capture process, we have applied the capture rate to the entirety of gate-to-gate emissions. This makes the capture rate applied for ammonia production more generous than it would likely be in reality.

One exception is that capture rates have not been applied to the emissions from urea production, which involves combining ammonia with carbon dioxide.[81] In this process, carbon dioxide is later emitted from urea as it is used (see "End-of-Life Emissions" section above).

As a sensitivity analysis we also applied the claimed CCS capture rates to gate-to-gate emissions for each facility with a proposed CCS system. On the other hand, we included a scenario where CCS processes are not applied, representing the many cases where CCS plans have proven either technically or economically infeasible.

Several planned projects make claims of extraordinarily high capture rates; for example, Adams Fork Energy, LLC, CNX Resources Corp claimed in a press release that they can produce ammonia with a "CO_2 capture of more than 99%" based on their use of Autothermal Reforming (ATR) technology.[82] According to the IEA Hydrogen project database, no ATR projects are currently operational, and only three have reached the construction stage, including one in the United States, the OCI Beaumont Clean Ammonia Complex. It is, therefore, difficult to assess the actual likely capture rate of ATR facilities. ATR systems may be able to achieve a capture rate of 90% or more. However, this comes at the cost of much higher power usage with an energy-intensive air separation unit, meaning any benefit may be substantially offset by the carbon emissions from the power used to fuel the operation.[83]

The emissions from the CCS process, for example, from powering the capture system, significantly reduce the apparent efficiency of carbon capture systems. However, figures taking into account these energy costs are rarely available. These emissions can be far higher when the process is powered by gas, which also yields more methane emissions. A 2021 academic study found that with an assumed capture rate of 85%, a methane leak rate of 3.5%, and using a twenty-year GWP, blue hydrogen would likely only result in a 9–12% reduction in GHG emissions compared to 'gray' hydrogen made without carbon capture.[84] Critically, the study also found that, if used for energy, blue hydrogen would result in greater greenhouse gas emissions than if gas were burned directly.

Several projects have production capacity estimates available but do not have claimed carbon capture rates available. In these cases, we have applied our base case carbon capture rates for the claimed CCS rate analysis.

Our analysis aims to highlight the varying outcomes of a CCS-enabled petrochemical buildout, the level of emissions that can and cannot be captured, as well as the scenario where planned CCS systems fail to operate as planned, as they so often have.

Uncertainties

Estimates of emissions from the petrochemical industry inevitably include uncertainties. Most industry datasets do not include estimates of uncertainty. The C-THRU project has innovatively explored the issue and has been able to quantify the uncertainties in its estimates of global petrochemical emissions. In its estimate that the global petrochemical industry in 2020 produced 1.9 Gt in CO_2e emissions, it found an uncertainty range of ± 0.6 Gt, a 34% uncertainty. Most petrochemicals analyzed had a 15–40% uncertainty range.[85]

These uncertainties stem from a range of factors, including lack of available data and industrial secrecy, as well as other factors explored below. In addition to this acknowledged and quantified uncertainty built into the emissions factors provided by C-THRU, which we show in our findings, there are other factors that create uncertainty in our specific analysis of potential petrochemical production. The quantified uncertainty methodology is set out in Cullen et al.[86] but, in summary, includes:

- Process uncertainty results from the fact that a range of processes and, therefore, emissions factors often exist for each product in the petrochemical industry. The details of which process is being used at any given facility are often limited, with industrial secrecy playing a significant factor.
- Allocation uncertainty stems from the difficulty in assigning the emissions to different co/byproducts from the same process. Some coproducts are not described in public literature.
- Feedstock uncertainty can stem from assumptions made about the kind of feedstock used, the exact quantity required, and upstream emissions.
- Direct energy uncertainty can come from variation in the exact quantity of gas or oil combusted in a process. There may also be variation in the stoichiometric ratio — the mix of how much air and flammable gas is present in combustion — which may also impact the emissions from the process.
- Variance in the amount of energy used may also introduce uncertainty in indirect energy emissions.

There are further uncertainties where we have gone beyond the C-THRU modeling. For example, disclosed production capacity estimates may not give an accurate picture of what production will look like in the future or account for the fact that companies may double count in calculating their capacity estimates. For example, a project promoter may claim that they have the capacity to produce 1,000 metric tons of ammonia and 1,000 metric tons of nitrogen fertilizer. In such a case, we have assumed that they could produce both as final products when, in fact, they could produce one or the other with the ammonia being needed as feedstock for the fertilizer.

As explained in the methodology section above, the C-THRU emissions factors build in assumptions around methane leakage rates. The conservative figure adopted from the GREET database results in a significantly lower estimate of GHG emissions compared to the result that would be expected with a higher and more accurate methane leakage rate.

Hydrogen leakage could also be significant to our analysis, given the projected quantity of ammonia and methanol production, which relies on hydrogen production. Hydrogen is not a direct greenhouse gas but has an indirect effect eleven times worse than carbon dioxide over a one-hundred-year span.[87] Hydrogen impacts the chemistry of the troposphere and the stratosphere, stretching the lifetime of methane, increasing the concentration of water vapor, and decreasing ozone — all of which affect the climate.[88]

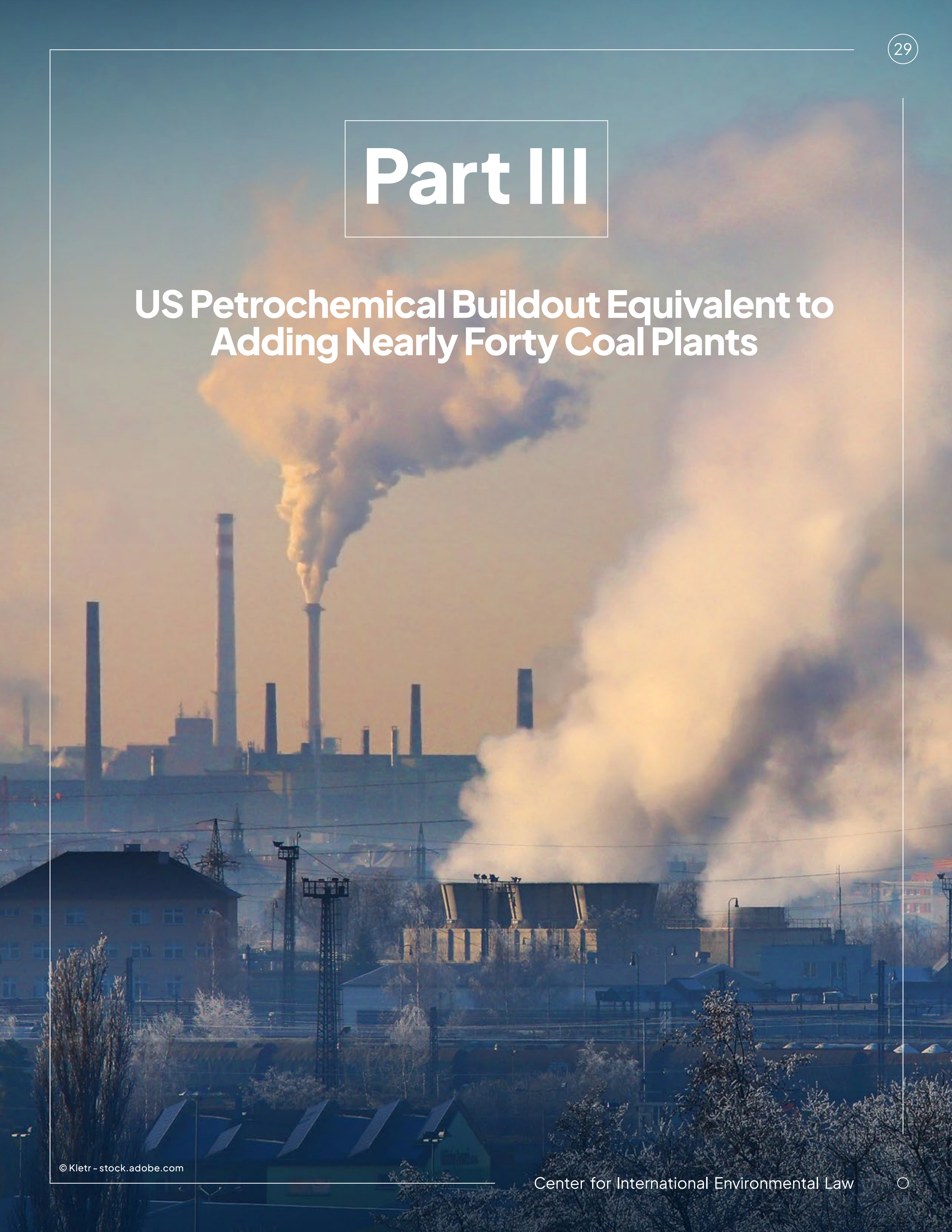
We do not include estimates for emissions from the transportation of petrochemical products, though much of the planned buildout may be to create products for export and, therefore, would likely entail significant transportation emissions.

Our addition of end-of-life and use emissions for final products also introduce uncertainties. We rely on recent incineration and recycling rates, but these could change in the future.

Given the uncertainties around the new demand for ammonia as a fuel and the lack of definitive data around ammonia engine emissions, we have not included emissions from burning ammonia as fuel in our analysis — though it is clear that burning ammonia can produce high nitrous oxide (N_2O) emissions.[89] Nitrous oxide (N_2O) is a very powerful greenhouse gas with a greenhouse warming potential 273 times stronger than carbon dioxide over one hundred years. N_2O emitted today remains in the atmosphere for 121 years on average.[90] Even a small amount of N_2O emissions could offset the reduction in emissions of using ammonia compared to diesel engines. Unburnt ammonia, emitted due to incomplete combustion in an engine, could also produce emissions and pose a toxic threat to humans and the environment.[91]

Part III

US Petrochemical Buildout Equivalent to Adding Nearly Forty Coal Plants



Findings

Our analysis finds that the proposed petrochemical buildout in the US would cause 153.8 MMT CO_2e ± 19.9 in additional annual emissions. If built to plan, this would add more greenhouse gas emissions per year than those of all US commercial aircraft combined.[92] These new petrochemical facilities would add the equivalent of 2.4% of US annual greenhouse gas emissions, even while the country pushes to reduce emissions.[93]

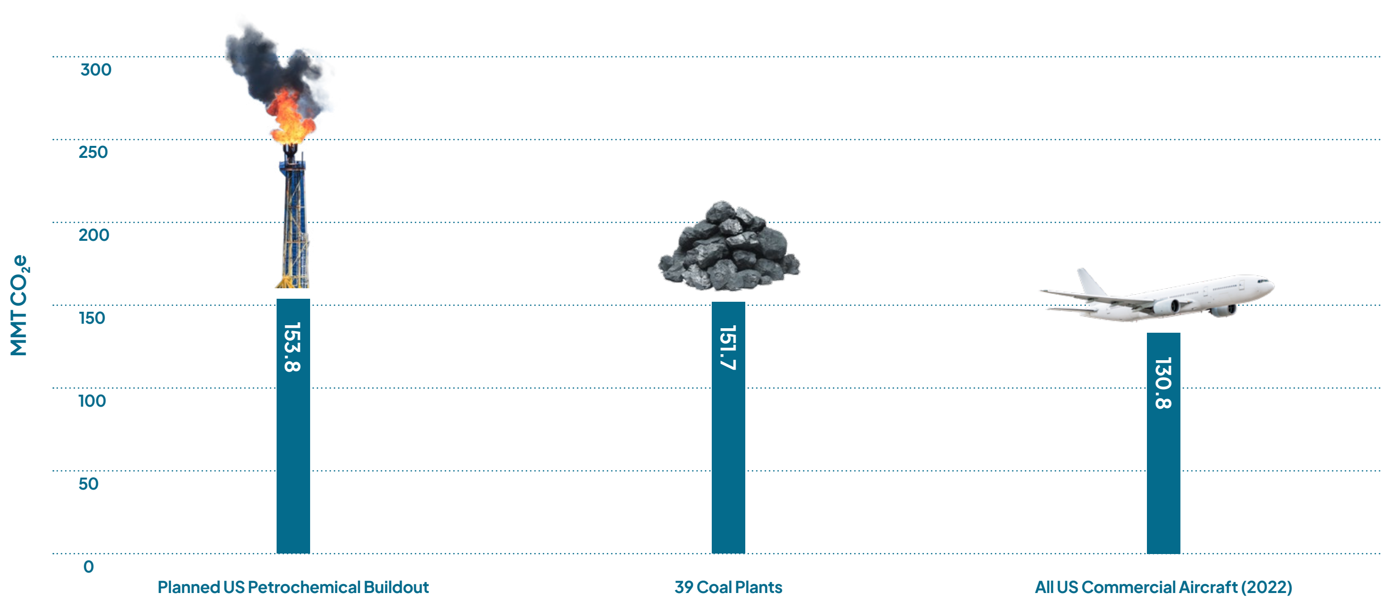
Put another way, each year, these US petrochemical projects would result in more greenhouse gas emissions than thirty-nine coal power plants.[94] In less than two years of operation, the greenhouse gas emissions from these collective petrochemical projects would outweigh the emissions of the oil extracted through the controversial Willow project over its thirty-year lifespan.[95] The typical lifespan of petrochemical plants is thirty years, meaning that this buildout would lock us into massive annual emissions for decades to come.[96]

Planned US petrochemical facilities would add 38% to current estimated cradle-to-gate emissions from US petrochemical production, according to C-THRU estimates.[97] Even when the emissions of new production of intermediary chemicals are ignored, production of final petrochemical products alone would create 108.3MMT CO_2e ± 12.3.

Our projected emissions estimates are likely conservative, as production capacity estimates were only available for around two-thirds of potential projects. In addition, the emissions factors used rely on US government data estimates of methane leakage of only 0.9%, though recent estimates put the US methane leakage rate at around three times that level.[98]

Annual GHG Emissions from the US Petrochemical Buildout Are Equivalent to Adding Nearly Forty Coal Plants

Annual GHG emissions from the planned US petrochemical buildout would be equivalent to adding nearly forty coal power plants' annual emissions, and is more than all US commercial aircraft annual emissions.



Source: CIEL analysis, Inventory of US Greenhouse Gas Emissions and Sinks: 1990–2022 US Environmental Protection Agency (EPA), emissions from jet fuel consumed by domestic operations of commercial aircraft.

Our estimate of potential GHG emissions from the buildout is two-and-a-half times higher than the estimates provided by project promoters during permitting processes, which totaled 55.7MMT CO_2e per year. This reflects both our sample's wider coverage of potential projects and broader coverage of the life cycle of emissions.

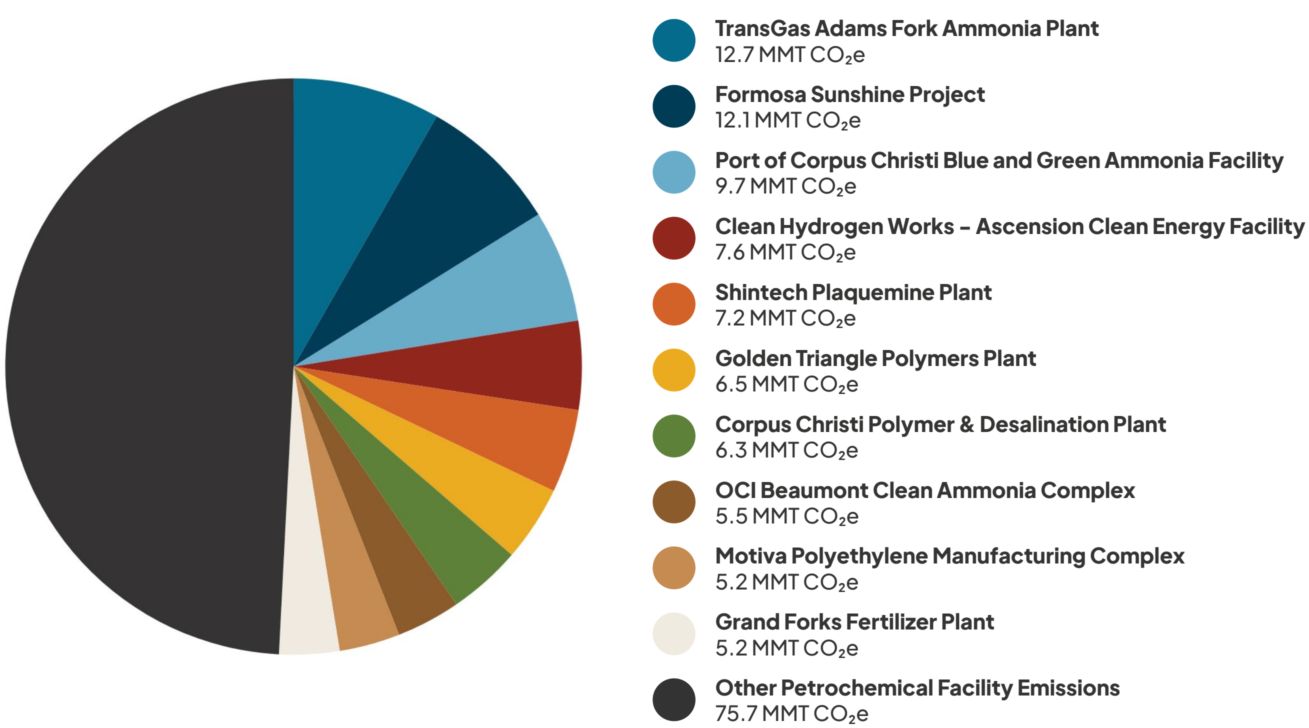
Several megaprojects make up an outsized proportion of potential emissions. The single largest proposed project is Adams Fork Energy's ammonia project in West Virginia, with 12.7 MMT CO_2e in potential emissions. Followed by Formosa's Sunshine Project in Louisiana, with 12.1 MMT CO_2e, and the Port of Corpus Christi's ammonia project in Texas, with 9.7 MMT CO_2e. The largest ten planned facilities make up more than half of potential emissions from the proposed buildout, while the largest twenty facilities make up nearly three-quarters of the potential emissions.

Eleven projects for which we were unable to source production capacity estimates had disclosed GHG emissions estimates in air permitting documents collected in the Oil and Gas Watch database. These emissions totaled 7.6 MMT CO_2e per year. The majority of the potential emissions came from one project, the ETF/ Nederland Ethylene Cracker in Jefferson County, Texas, which disclosed an emissions estimate of 5.1MMT CO_2e per year.

These eleven projects have not been included in our totals to avoid mixing our data. However, we note that they amount to considerable additional potential emissions, as would the thirty-six projects for which we were unable to find production estimates.

The Majority of Petrochemical Emissions Will Come from A Handful of Megaprojects

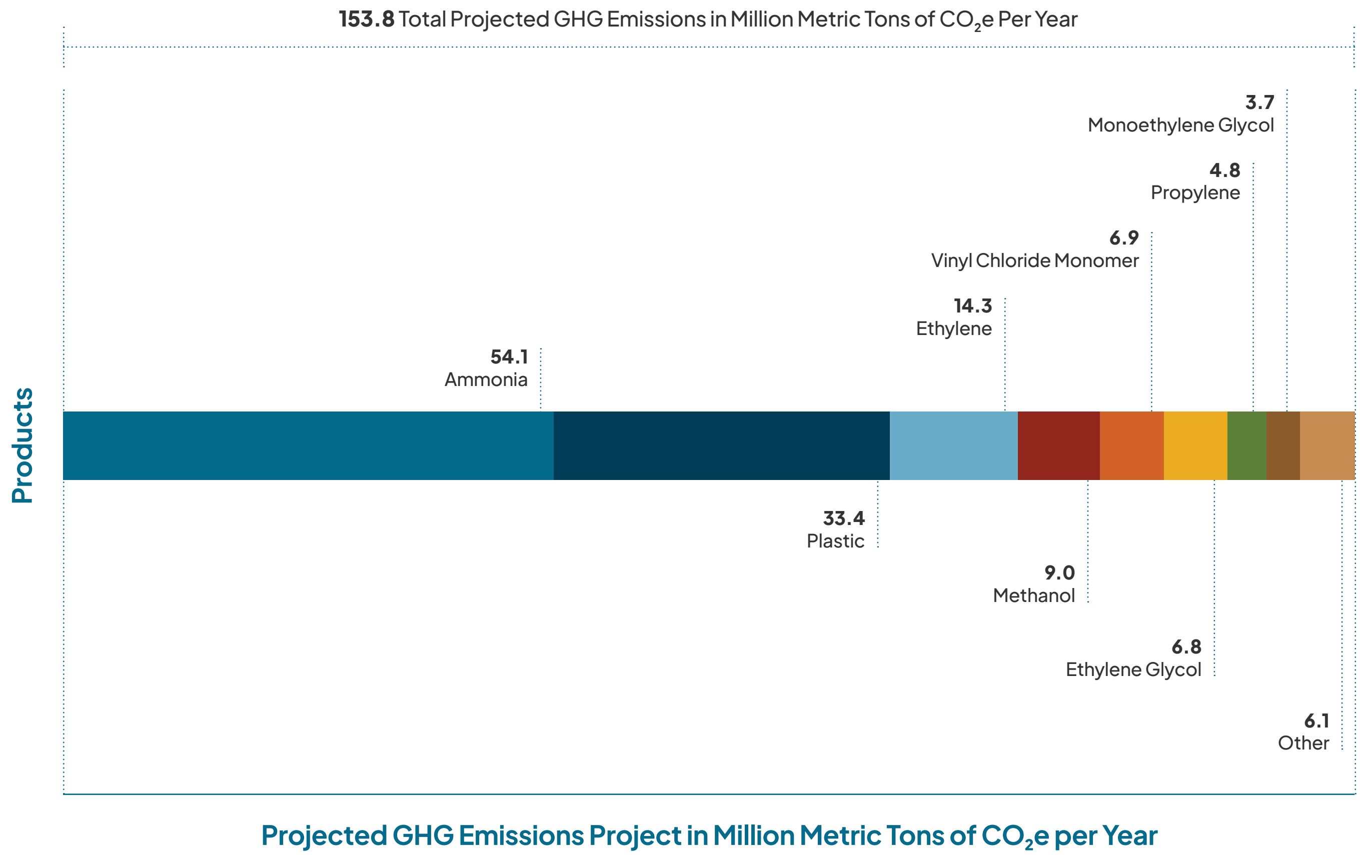
The ten largest projects make up more than half of potential GHG emissions from the US petrochemical buildout.



Source: CIEL analysis

Ammonia and Plastic Projects Will Cause the Most Pollution

Emissions from plants that manufacture ammonia and plastic will make up the majority of emissions.



Source: CIEL analysis

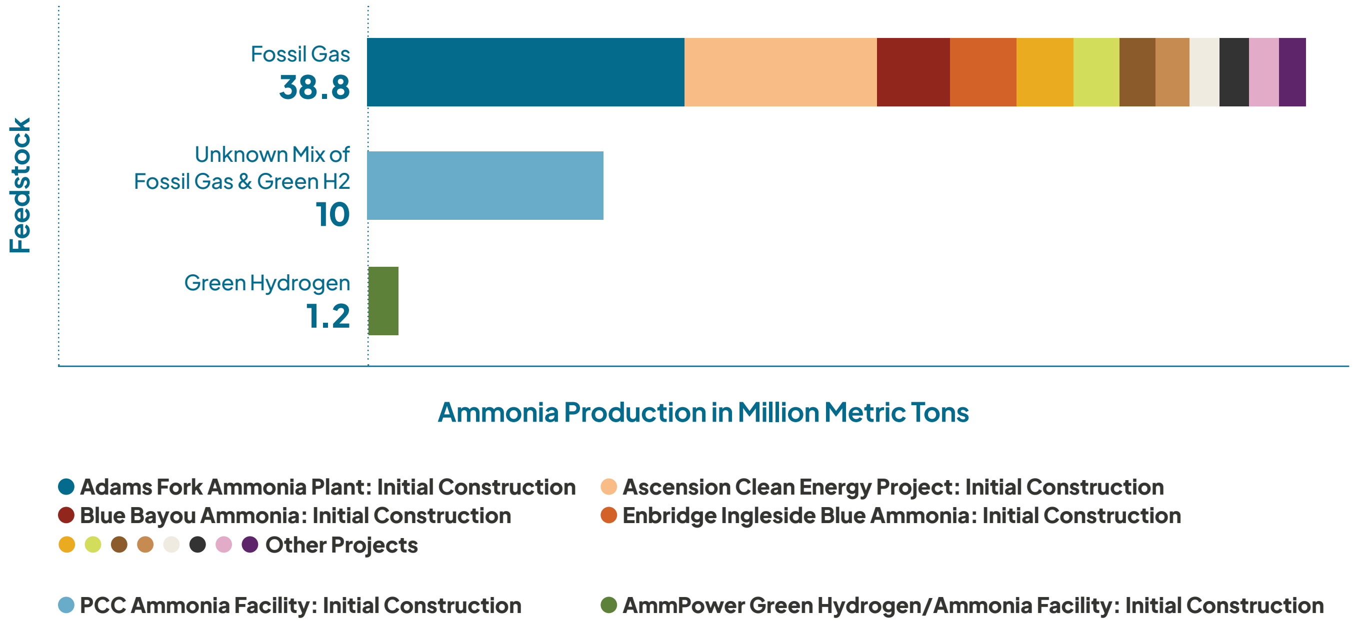
A striking proportion of emissions from planned petrochemical projects will come from the manufacturing of ammonia. At least 54.5 MMT in new ammonia production capacity is planned, which would nearly quadruple current US ammonia production. Actual planned production is likely to be even higher as eight of the planned thirty-three ammonia projects did not have production capacity estimates available.

The US currently produces around 14 MMT of ammonia annually.[99] Currently, in the US, 88% of ammonia production is used to make fertilizers, with the remainder used for industrial purposes — including the production of plastics, synthetic fibers, and explosives. Ammonia production is highly energy intensive and polluting. Global ammonia production accounts for around 2% of total final energy consumption and 1.3% of CO_2e emissions from the energy system.[100]

This vast increase in ammonia production seems unlikely to be orientated toward fertilizer production and appears aimed at ammonia's potential use as a fuel for shipping or as a means of exporting hydrogen. In project descriptions, the majority of proposed ammonia projects — which constitute a major proportion of the petrochemical buildout — mention the use of ammonia as either a way to export hydrogen-based fuels for use as a shipping fuel or for its use in power stations.

The Majority of Ammonia Projects Rely on Fossil Fuels

Though often touted as 'climate solutions,' most ammonia projects rely on fossil gas rather than green hydrogen as feedstock.



Source: CIEL analysis

Green ammonia, made from hydrogen electrolyzed using renewable electricity, is being widely projected as a potential fuel to replace dirtier shipping fuels. However, up to 95% of planned US ammonia production is based on fossil fuels. If constructed, the plants would lock in vast emissions and fossil fuel demand for decades to come, undercutting any claim these projects have of being climate-friendly.

When combined, the high GHG emissions from fossil ammonia production and the potential GHG emissions from burning ammonia make fossil-fuel-based ammonia fuel far from 'green.'

Plastics also account for a substantial proportion of planned new production, with 19% — or 29.6 MMT CO_2e — of the proposed new buildout emissions coming from plastics.

In addition to plastics themselves, chemicals that often serve as feedstock for plastic production make up 39.9MMT CO_2e per year in potential emissions, another 26% of the buildout. The proposed plastic feedstock production includes ethylene, ethylene dichloride, ethylene glycol, ethylene vinyl alcohol copolymers, monoethylene glycol, propylene, PTA (purified terephthalic acid), and vinyl chloride monomer.

Ethylene alone, a core chemical used to make a wide range of plastics, constitutes a significant portion of the planned buildout. Eleven ethylene projects are planned with a production capacity of 12.6 MMT, resulting in 14.4MMT CO_2e in annual emissions. These figures do not include production from two projects, the Nederland Ethylene Cracker and the CP Chem Port Arthur Plant — Unit 1544 Expansion. However, the Nederland Ethylene Cracker has disclosed massive potential emissions of 5.1 MMT CO_2e through the permitting process, suggesting that an even larger ethylene production buildout is in the cards.

Interestingly, 30% of potential petrochemical buildout emissions come from projects that are currently on hold. Projects totaling emissions of 46.1 MMT CO_2e per year have been paused, including several of the largest planned projects such as Formosa's 'Sunshine' plastics project in St. James Parish in Louisiana, Corpus Christi Polymers' 'Jumbo project' to expand plastics production in Texas, IGP Gulf Coast's Methanol Complex in Louisiana, and PTTGC America's Petrochemical Complex in Ohio. Potential emissions from projects on hold alone are equivalent to more than ten coal power plants' worth of emissions.

Many of the projects on hold are plastic production facilities. **Notably, nearly 60% of planned plastic production projects by emissions are on hold, showing that a combination of local opposition and market forces is beginning to constrain the expansion of plastic production.**[101] Projects that could emit a further 13.1 MMT CO_2e per year manufacturing plastic precursor chemicals are also on hold.

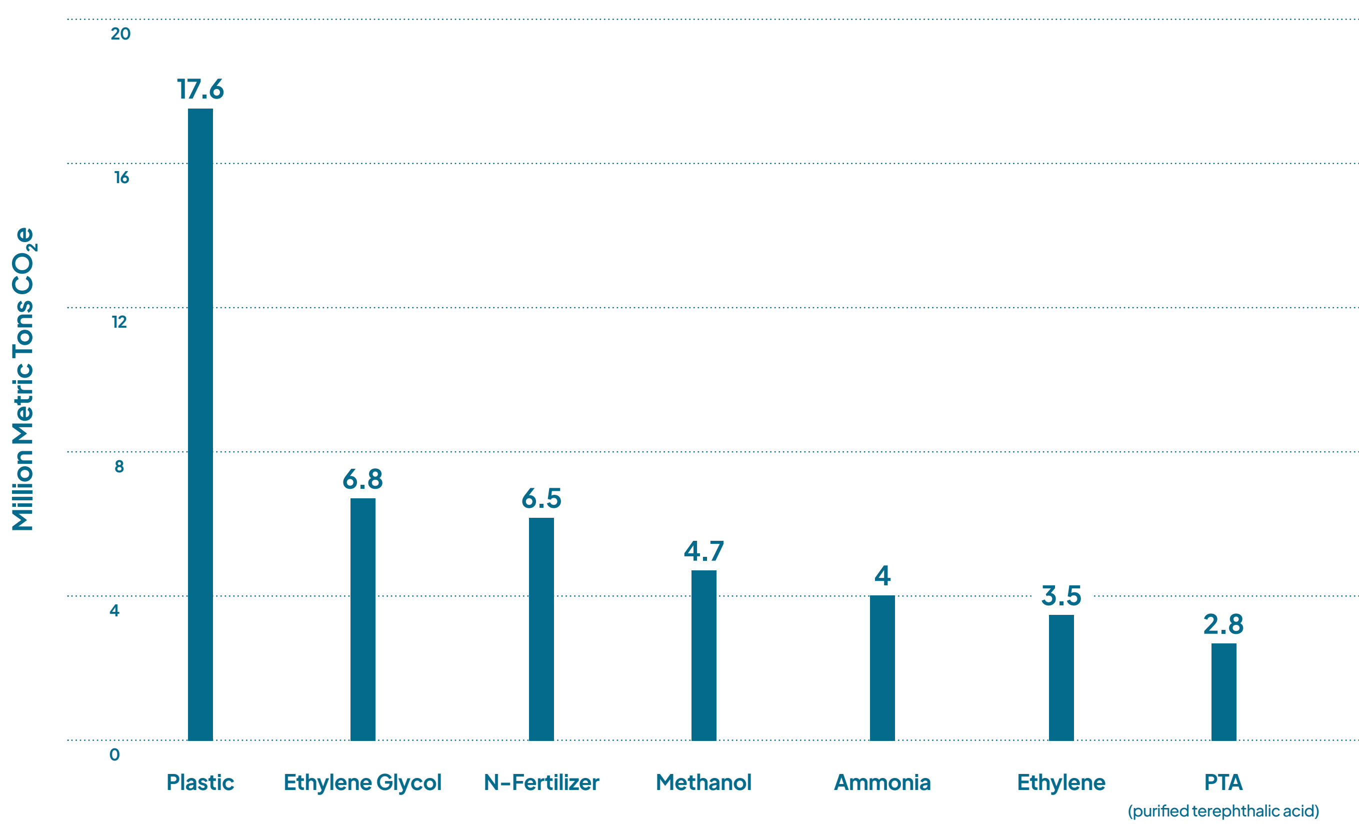
Recent industry analysis suggests that the construction of new global petrochemical facilities has led to an excess of capacity, especially in plastic manufacturing, and has reduced the utilization of existing plants. In 2023 approximately ten MMT per annum of new ethylene cracker capacity seems to have caused the utilization of ethylene plants to drop to around 80% while other chemical production utilization dropped to ten-year lows.[102]

Legislation in every region of the world has seen countries move to ban, restrict, and phase out many kinds of single-use plastic products, potentially causing further financial risks to investors in new plastic production. Between 2012 and 2022, 731 plastic pollution policies were introduced worldwide.[103] Carbon Tracker has estimated that moves toward a circular economy with new targets, taxes, rules, and regulations could lead to reduced demand for plastics and risks up to US$400 billion in stranded assets in the petrochemicals sector.[104]

The delay in so many massive petrochemical production projects suggests that **investors already perceive significant risks around petrochemical projects, especially around plastic,** and that the tide could turn against this massive quantity of new production.

Plastic Production Projects are Being Held Up

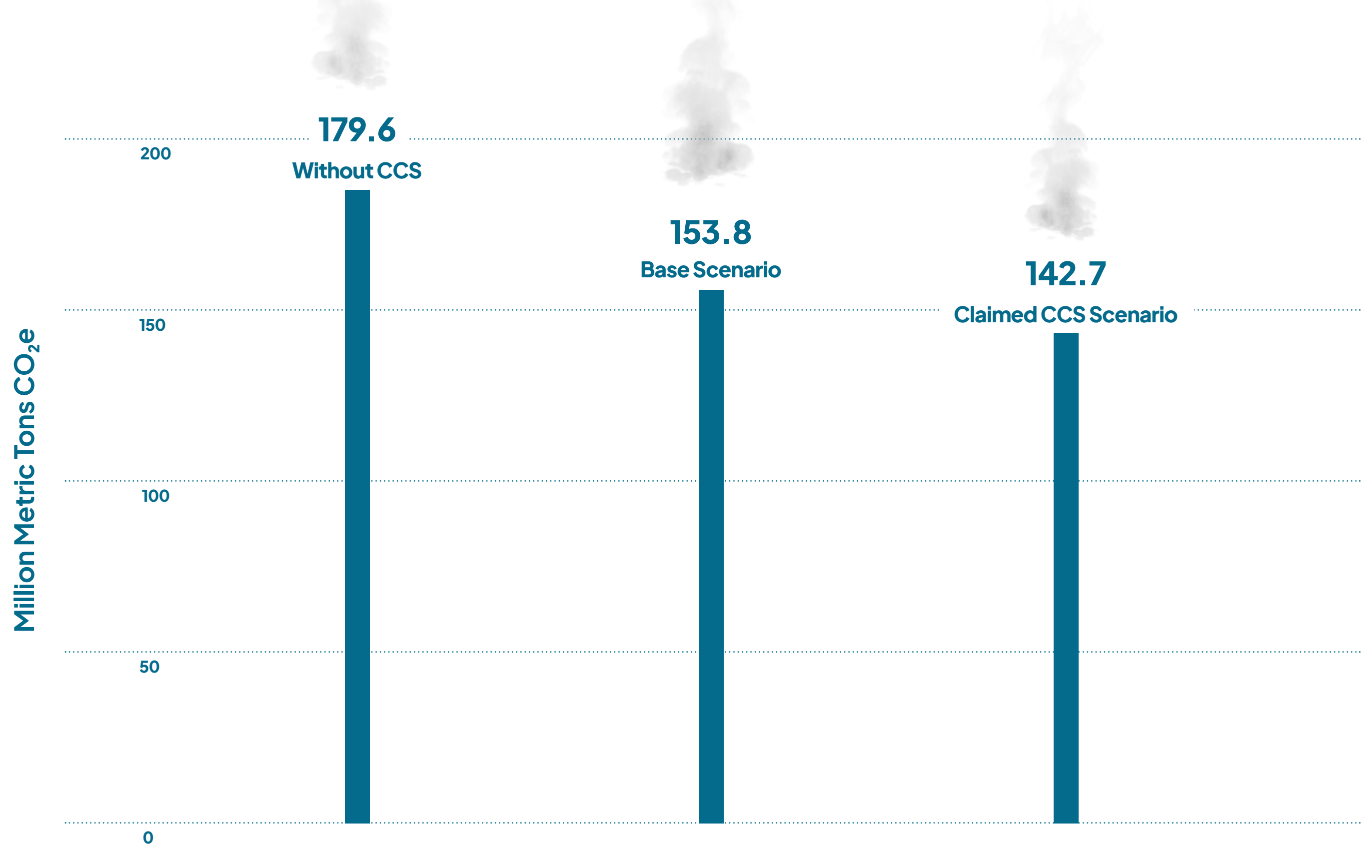
The type of projects on hold, in order of emissions output



Source: CIEL analysis

With or Without Carbon Capture, Fossil Fueled Emissions Remain High

Whether CCS is in place or not, emissions for the buildout remain high across all CCS scenarios.



Source: CIEL analysis

Our base scenario, which assumes some carbon capture effects, found total buildout emissions to amount to 153.8 MMT CO_2e per year. Our claimed CCS scenario, which takes into account the highly optimistic claimed carbon capture rates from project promoters, lowers total emissions to only 142.7 MMT CO_2e per year (a less than 10% reduction overall). This reality underscores that even in the unrealistic scenario, where CCS captures nearly all the emissions the industry purports, emissions from the petrochemical buildout remain high.

A third scenario, where planned CCS fails to work and no emissions are captured, results in potential annual emissions of 179.6 MMT CO_2e. Given the history of CCS systems proving economically or technically infeasible, this scenario more closely demonstrates the real risk of allowing projects to move forward based on their CCS-related claims.

When projects are narrowed down to only those that propose to include CCS systems, it is clear that CCS is exclusively being deployed in facilities making ammonia and methanol, though they may also make other related products. These facilities combined stand to contribute 58.1 MMT CO_2e in annual emissions in our base case scenario, rising to 83.9 MMT CO_2e if the CCS fails to operate. Because a sizable proportion of emissions that come from ammonia and methanol projects stem from upstream fossil fuel feedstock production or downstream fertilizer field application, the actual quantity of emissions that CCS could capture is quite limited.

Discussion

The planned petrochemicals buildout in the United States is a profound threat to the climate. Petrochemical production and use already produce and enable significant greenhouse gas emissions. Plastics and fertilizers alone contribute around 7.3% of global greenhouse gas emissions. The scale of potential petrochemical-related emissions growth is vast, and the true climate impact of the petrochemicals sector is likely far worse than is reflected in our modeling. A significant part of the buildout is being subsidized under the guise of climate action despite contributing so significantly to increased emissions. The mismatch between climate-friendly rhetoric and the reality of the polluting petrochemicals buildout is a clear demonstration of the dangerous climate distractions that carbon capture and storage, fossil hydrogen, and fossil ammonia present.

The scale of climate impacts is likely far greater than modeled.

Gaps in transparency, data, and knowledge hampered full accounting of the emissions impact of the petrochemical buildout. These gaps inevitably lead any modeling to downplay the climate impact of petrochemical production, use, and disposal. In reality, the total greenhouse gas emissions from current and planned petrochemical production may be far worse than the already alarming estimates suggest.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Plastics and fertilizers alone contribute around **7.3% of global greenhouse gas emissions**

One of the primary gaps in our analysis is strictly informational. Of the 118 projects in our data set, only 74 had publicly available estimated production figures, and for production at 3 facilities, reliable emissions factors were not available. Given the role of megaprojects in driving emissions, any one of the 47 projects for which we could not generate emissions estimates could ultimately make significant contributions to the overall climate impact of the planned buildout.

As noted in our Methodology section, the impact of methane emissions is almost certainly underestimated, as measured methane emissions are significantly higher than those used in the GREET model, and their impacts are diluted by using a one-hundred-year global warming potential.

The use of petrochemicals may also be disrupting the ability of soils and oceans to sequester and store carbon dioxide on significant time scales. These impacts are hard to measure but may be significant, especially if and as the production and use of these chemicals increase.

Finally, there are two sources of greenhouse gasses that are difficult to project but critically important to consider — hydrogen and nitrous oxide. Hydrogen, the primary feedstock for ammonia, is an indirect greenhouse gas, meaning it does not directly trap heat in the atmosphere, but it does increase the longevity of other greenhouse gasses, particularly methane.[105]

Hydrogen is the smallest molecule in the universe. It easily passes through many materials and has embrittling effects on many metals. It, therefore, presents a significant risk of leaking.[106] The expansion of the hydrogen production system undergirding an expansion in ammonia production presents serious risks of direct emissions of hydrogen into the atmosphere.

There is also a great risk of emissions of nitrous oxide where ammonia is used as fuel. When fuels are burned, some fraction is only partially combusted, while another fraction escapes combustion altogether. With respect to ammonia, this presents the risk of high nitrous oxide emissions from partial combustion, as well as 'ammonia slip' where unburned toxic ammonia is released from tailpipes.[107] The potential greenhouse gas impact of ammonia as fuel is significant. Given nitrous oxide's great heat-trapping power — 273 times that of carbon dioxide over a one-hundred-year time frame — even fairly low rates of partial combustion and leakage can have great climate consequences, undermining or even undoing any purported climate benefit from ammonia use in the first place.

A large part of the buildout is falsely justified by 'climate action.'

The massive expansion of petrochemicals and its associated greenhouse gas impact is driven by the anticipation of new markets for petrochemicals, in part supported by climate subsidies. The combination of fossil-based ammonia and methanol production with carbon capture and storage is a key pillar of fossil fuel industry efforts to develop a new energy economy where fossil fuels remain central, laundered into fuels that can be marketed as 'clean.' Tax credits introduced under the Inflation Reduction Act could translate into $100-$150 per tonne of fossil-based blue ammonia.[108] These projects, however, represent a serious climate threat.

The great proposed expansion of ammonia production is likely premised in large part on its assumed potential for use as a shipping fuel and as a way to transport hydrogen. Shipping is considered a sector with limited options for eliminating fossil fuels, and ammonia is a leading alternative in industry plans for their replacement. When combusted, ammonia produces no carbon dioxide and, as such, is conceptually well-suited for this role. There are, however, practical challenges to using ammonia as a shipping fuel, including its toxicity to marine environments and human health.

Ammonia has several advantages as a means of transporting hydrogen compared to liquifying and shipping hydrogen. However, reconverting ammonia into hydrogen is energy-intensive and costly.[109] Recent analysis has suggested that cracking ammonia back into hydrogen adds around 50% to the resulting cost of hydrogen, raising questions over whether ammonia would then just be burned as a fuel or used for fertilizer production instead.[110]

The existing use of ammonia for fertilizer is also contributing to significant greenhouse emissions and other harms, with around two-thirds of greenhouse gas emissions from nitrogen fertilizers occurring in their use phase, while also leading to degradation of soil quality.

Nitrogen pollution also leads to eutrophication — a process that results in algal blooms, dead zones, and fish kills — pushing society far beyond the planetary boundary for nitrogen pollution. The high emissions from fossil ammonia production, together with the practical limitations of ammonia and its potential greenhouse gas emissions when used as a fuel, should raise concerns over the development of a large ammonia economy.

As demonstrated in our analysis, ammonia carries a large, embedded climate impact when made with fossil fuels. Even before it is burned as fuel, the process of producing ammonia has already had a large impact. Even in our most generous scenario, where capture rates are unrealistically high and cover an unrealistically broad swath of emissions sources from production, the overall emissions from ammonia production with carbon capture remain high. **Fossil-based ammonia is simply not a climate-friendly fuel and should not be treated as such.**

Much of the petrochemical buildout is being boosted by federal subsidies.

The growing use of carbon capture and storage (CCS) systems to justify new fossil fuel projects, especially using hydrogen, is supported by extensive government subsidies. Section 45Q of the Internal Revenue Code, which hands out tax credits for captured carbon, was dramatically increased through the Inflation Reduction Act of 2022. The tax credit is worth up to $85 per tonne of CO_2 stored and $60 per tonne even if the CO_2 is used for enhanced oil recovery, where CO_2 is used to increase production from an oil field.[111] 45Q could add up to $0.80 in subsidies per every kg of hydrogen in projects with carbon capture.

45V is a separate tax credit subsidy available for hydrogen production based on estimated lifecycle greenhouse gas emissions per kilogram of hydrogen (kg CO_2e/kg H2). 45V may be more advantageous in projects with higher capture rates recorded, though estimates of the emissions from hydrogen production for the subsidy are premised on very low methane leak estimates, meaning that estimated emissions may be misleading.

These two federal subsidies could send vast amounts of US taxpayer funds, even to projects that only ever achieve modest carbon capture rates — further subsidizing the expansion of fossil fuel emissions.[112]

One of the projects for which carbon capture and storage is proposed is methanol production. Methanol has received less hype than ammonia as a clean fuel, in part because it still releases carbon dioxide when burned. However, proponents are actively promoting methanol as a potential 'e-fuel' made from hydrogen and captured carbon dioxide, and many see a role for methanol as a future fuel alongside ammonia.[113]

Finally, there is the rapid expansion of plastic production. While plastics facilities themselves do not appear to be taking advantage of subsidies for CCS or hydrogen production, plastics companies are increasingly positioning themselves as part of the energy transition. Many of the companies behind these proposed plastics facilities justify their product on thinly veiled climate or environmental grounds, often through industry trade groups.[114]

Conclusions and Recommendations

Petrochemicals present a vast and rapidly growing threat to the global climate. In the United States, a substantial expansion in production capacity is planned following what has already been a decade of growth. If the petrochemical buildout proceeds as planned, it will add 153.8 MMT CO_2e ± 19.9 in additional annual emissions, equivalent to more than 39 coal plant's annual emissions, and lock in fossil fuel production for decades to come, all in this crucial decade for decisive climate action.

A large part of the planned buildout of petrochemical facilities is supported on climate grounds despite the enormous emissions impact of the planned projects. Fossil ammonia is justified with carbon capture and storage. In reality, CCS fails to clean up ammonia production and does not cut its fundamental tether to fossil gas, nor its associated greenhouse gas emissions. Unfortunately, these projects are eligible for generous subsidies from the federal government despite their significant contributions to US greenhouse gas emissions.

Even though the known climate impact of petrochemicals is severe, the true extent of the damage will be worse than we currently understand and beyond what we can currently quantify. Plastic pollution appears to be interfering with fundamental aspects of the global carbon cycle, potentially disrupting and slowing the oceanic carbon pump. The use of ammonia as fuel may become a major source of nitrous oxide, an extraordinarily powerful greenhouse gas that could undercut any climate benefit from using this fuel.

Permitting authorities should reject the expansion of the petrochemical industry. It is irresponsible on climate grounds, detrimental to the ecosystems already inundated with agrochemicals and plastic pollution, and presents yet another threat to the human rights of communities already unjustly overburdened with industrial pollution.

In addition to the imperative need to stop the petrochemical buildout, and in light of the massive greenhouse gas profile of this planned buildout, we recommend:

1.

- **The President and climate policy leaders should:**
  - Publicly and officially acknowledge the role of petrochemicals in driving and exacerbating the climate crisis.
  - Publicly acknowledge that the full life-cycle scope of the future plastics treaty covers petrochemical production and its associated toxic impacts, in line with the July 2024 Interagency Policy Committee action plan on plastic pollution.
  - Highlight the need for the US to support legally binding measures in global plastics treaty negotiations to stop the expansion of petrochemical production facilities, including through mandatory global targets for production reduction.

2.

- **No national or state government, agency, policymaking body, or corporation** should consider hydrogen, ammonia, or methanol produced from fossil fuels with carbon capture as a 'clean' or 'climate-friendly' fuel or product. Incentives to finance or trade in such products should be eliminated.

3.

- **Banks, insurers, private equity financiers, and public finance institutions (including the US international finance institutions)** should prohibit financing for petrochemical production expansion, and petrochemical production should be understood to be in direct conflict with commitments to meet climate targets.

4.

- **Congress should:**
  - End polluter welfare by removing federal subsidies for carbon capture and fossil hydrogen production, including eliminating the 45Q tax credit for carbon sequestration and, at minimum, ensuring the 45V tax credit for hydrogen production cannot be used to make fossil-gas-derived hydrogen and ammonia.
  - Amend the Infrastructure Investment and Jobs Act (IIJA) to ensure that the funding it authorizes is not steered to fossil-based hydrogen under false pretenses of 'low-carbon' production.

5.

- **The Environmental Protection Agency, state permitting agencies, and state environmental protection bodies** should pause issuance of any new permits unless and until protective measures for local communities are in place, including a requirement for fenceline monitoring, verification, reporting, disclosure, and transparency of all emissions at existing and proposed facilities, including greenhouse gasses and air pollution. It should be demonstrated that proposed petrochemical facilities will not impact human health, particularly in fenceline communities, and will not harm the environment or fuel climate change before any new permit is issued.

6.

- **Permitting authorities, health agencies, and other institutions,** when assessing the environmental impact of proposed petrochemical facilities, should consider the full health impact of such facilities, including, specifically, the expected health harms from climate change, as well as each project's contribution to the cumulative impacts from toxic emissions of other new and existing neighboring polluting facilities.

7.

- **The Department of Energy should:**
  - Update its GREET model to include a full accounting of real-world methane emissions from fossil fuel production.
  - Move to exclude fossil-based hydrogen projects from any justice-aligned designation, such as Justice40.

8.

- **Public funding should be made available to the scientific community** to undertake research to better understand the emergent or poorly understood health and climate risks of petrochemicals, including but not limited to the nitrous oxide impact of using ammonia as a fuel; the indirect greenhouse gas effect of hydrogen projects and their potential leakage rates; the impact of plastics on oceanic carbon cycling and the effect that could have on atmospheric carbon stocks; and the health impacts of the more than 10,000 petrochemicals for which hazards are unknown.

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