Sustainability Insights | Research

Decarbonizing Chemicals Part One: Sectorwide Challenges Will Intensify Beyond 2030

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Medium-term decarbonization targets are unlikely to materially affect chemical companies' cost structures but could imply more significant disruptions to the sector post-2030.

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This research explores how companies in the chemical sector are approaching decarbonization. We first assess the greenhouse gas concentrations across the sector's various manufacturing processes. We then look at the operational strategies and solutions that companies are adopting, or considering, to reduce their greenhouse gas emissions, including those emissions that are more challenging to address. Our research centers on chemical companies in the U.S. and Europe, where around 80% of our rated issuers in the sector are located. Out of a total of about 180 issuers in our rated universe globally, we have sampled 27 that we think are representative of the sector's decarbonization challenges. We also look at how their diverging regulatory frameworks could influence the industry's cost structures and capital spending needs. Part two of our research, "Decarbonizing Chemicals Part Two: The Credit Risks and Mitigants," discusses the specific credit risks and mitigants associated with decarbonization strategies and how these might influence our credit rating analysis.

Key Takeaways

- The interim decarbonization targets (typically by 2030-2035) of the chemical companies we rate are technically feasible without materially disrupting the sector's cost structures, and with limited financial impacts.
- **Decarbonization over that time frame could largely rely on energy efficiency gains and the electrification of certain processes.** It will also hinge on external factors such as the availability of sufficient renewable energy. Inconsistent regulation across regions, in globalized chemical markets, could create uncertainties and diverging effects.
- **Longer term decarbonization targets, on a roadmap toward carbon neutrality by 2050 for instance, could see greater shifts in product chains.** These could for example involve hydrogen-based manufacturing or greater carbon-capture capacities. Such shifts could prove more disruptive to the industry's cost structures, while early movers are likely to be better prepared to absorb transition-related impacts.

Key figures

3rd most emissive industry generating **3 billion tons of CO2** per year, or **5%-6% of global emissions**.

Direct CO2 emissions from **primary chemicals** account for **1/3 of the sector total**.

Efficiency gains and electrification across the sector **could achieve 30%-40% reduction in emissions by 2030-2035**, while cutting the remainder beyond that is likely to disrupt most intensive segments.

Clean hydrogen in sufficient quantity **could save 80%-90%** of emissions of ammonia-based fertilizers, and **lead the way to cleaner primary chemicals**.

A Complex Sector, Highly Aware Of Its Many Decarbonization Challenges

The chemical sector is one of the most complex and diverse in terms of interconnected value chains. Its products are critical to almost all aspects of modern life from health care and agriculture to construction and manufacturing. Chemicals production represents more than 1% of global GDP (Oxford Economics, 2019) and is also the third highest emitter of greenhouse gases among the industrial sectors according to the International Energy Agency (IEA), after the steel and cement industries. As a result, it is more exposed to changes in regulation and the associated carbon costs and investment needs, as well as evolving consumer preferences.

S&P Global Commodity Insights estimates that the chemicals industry consumes about 10% of all fossil fuels and generates around 3 billion metric tons of CO2e annually. This is more than any country in the world except the U.S. and China. Of all the industrial sectors, chemicals is the largest consumer of oil, gas, and coal. Fossil fuels are not only used for combustion to achieve the heat and pressure needed for chemical reactions but also as inputs or feedstock. Emissions stem from both energy consumed in production processes and directly from chemical reactions. The industry accounts for 5%-6% of global greenhouse gas emissions according to the IEA (which compares with 7%-8% each for the steel and cement industries).

In Europe, the chemical sector's total greenhouse gas emissions have fallen about 55% since 1990, according to the European Chemical Industry Council (CEFIC). Production meanwhile has increased by around 85% (chart 1). Emissions have also fallen by about 35% in the U.S. over the same period, according to the American Chemistry Council (ACC). This decline reflects reduced process emissions, despite volume growth, and technological improvements. Production advances have included nitrous oxide catalysts, the better re-use of by-products like methane, and regulation, notably on fluorinated gases. These gases have exponential greenhouse effects. They are a few tens (methane), hundreds (nitrous oxide), and tens of thousands (fluorinated gases) times more potent in terms of global warming than CO2. While these other gases have driven the decline in emissions over recent decades (chart 2), the sector's efforts to reduce the carbon dioxide footprint still have a long way to go, according to companies' set targets.

Chart 1

Total GHG emissions and production in the EU27 chemical industry

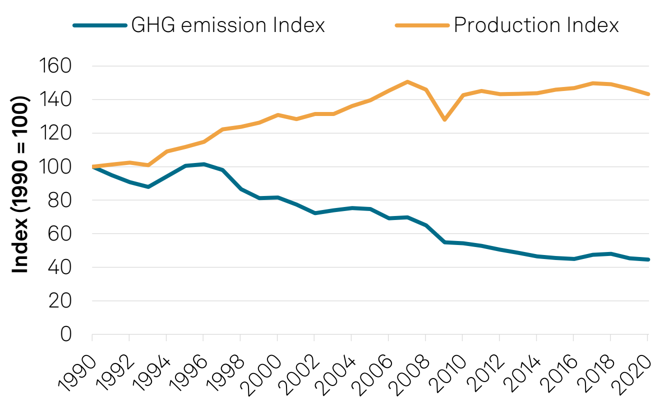
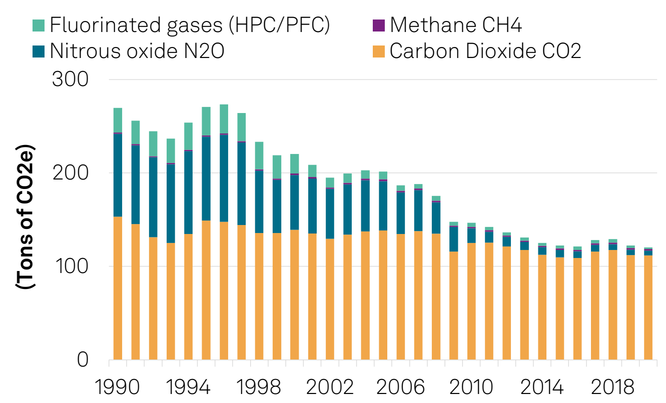


Chart 2

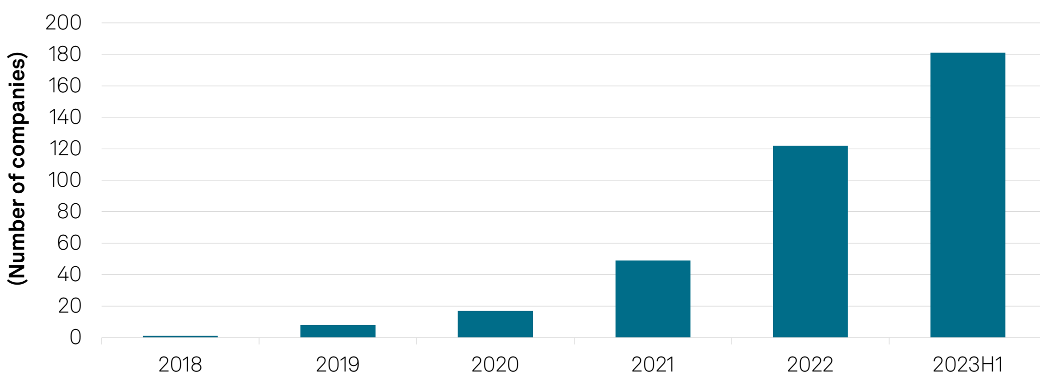
EU27 scope 1 GHG emissions fall by 149 million metric tons (CO2) since 1990



More than 70% of the world's top 100 chemicals producers have committed to carbon neutrality by 2050, and more have set interim targets, according to S&P Commodity Insights. BASF, the largest chemicals producer globally, has committed to a 25% reduction in its absolute scopes 1 and 2 emissions by 2025 compared to 2018. Other large international peers have also shared medium-term decarbonization commitments: for instance, Dow Chemicals Company has committed to a 15% reduction by 2030 versus 2020 (or a 30% reduction compared to 2005); and LyondellBasell Industries has committed to a 42% reduction by 2030 compared to 2020. All three companies, as illustrative examples, are aiming for carbon neutrality in terms of scopes 1 and 2 emissions by 2050. The number of chemical companies setting, or committing to set, targets through the Science Based Targets initiative has also grown significantly in the past five years (see chart 3), with an average scopes 1 and 2 reduction target of 40%-45% for 2030 or 2035 from base years between 2018 and 2022. Key industry bodies have also defined best practices for energy efficiency and the use of low-carbon fuels. The International Council of Chemicals Associations (ICCA), which represents more than 90% of global chemicals sales, aims to reduce the sector's energy use by over 40% and greenhouse gas emissions by 70% by 2050.

Chart 3

Cumulative number of chemical companies that have set or committed to set science-based targets



Source: Science Based Targets initiative, S&P Global Ratings.

Chemicals Production: Where Are CO2 Emissions Concentrated?

The chemical sectors' emissions are driven by the energy required to achieve the heat and pressure needed for chemical reactions, notably for the most energy-intensive steam cracking, reforming, and gasification. It depends heavily on fossil energy for fuel but also for feedstock to produce chemicals that—in the case of products flowing through petrochemical crackers—are carbon-based by definition. Manufacturing processes themselves can also release greenhouse gases as a by-product. Along with the relatively high integration between sizable chemical plants and connected product chains, all these factors make chemicals one of the most complex and challenging sectors to decarbonize. That said, a few chemical product chains account for a major portion of emissions. This makes it feasible for players in the sector to carve out decarbonization priorities. It also helps us analyze the potential impacts on our rated issuers' credit qualities.

The primary chemicals, or base chemicals, serve as building blocks for the intermediate and more downstream product segments. Typically, the oil and gas sector is the primary supplier of materials to the chemicals industry, while the chemical sector itself sells its products to many other downstream sectors including other industrial, agribusiness, consumer products, and more. Within the chemical sector, the basic transformation of hydrocarbons occurs early in the chemical product chain to extract key base chemicals, which then serve as building blocks for the rest of the sector. For example, ethylene is an olefin base chemical obtained from steam cracking of ethane or naphtha, which can then be converted to ethylene oxide, then to ethylene glycol, and then to polyester, a well-known synthetic fiber serving the textile industry. Base products are often referred to as upstream chemicals, while final products are considered downstream chemicals. Table 1 shows a simplified classification of chemical products along the product chain, from fossil feedstocks and fuels serving the sector, through to final products.

We estimate that the base chemicals segment comprises around one third of the chemical sector's total emissions. Emissions associated with feedstock production, intermediate products, and final products cause the remainder of emissions. Base chemicals include petrochemicals (olefins and aromatics producers) and the methanol and ammonia chains (which encompass hydrogen production and downstream fertilizers produced from ammonia). According to the IEA, around 1 billion metric tons of direct greenhouse gas emissions per year are emitted from the production of base chemicals. We therefore primarily focus our analysis on these product groups. Individual downstream production processes such as specialty chemicals tend to involve smaller batches and rely more on electricity versus upstream processes, and we touch only briefly on these in this research.

Table 1

Type of products along the chemical product chain

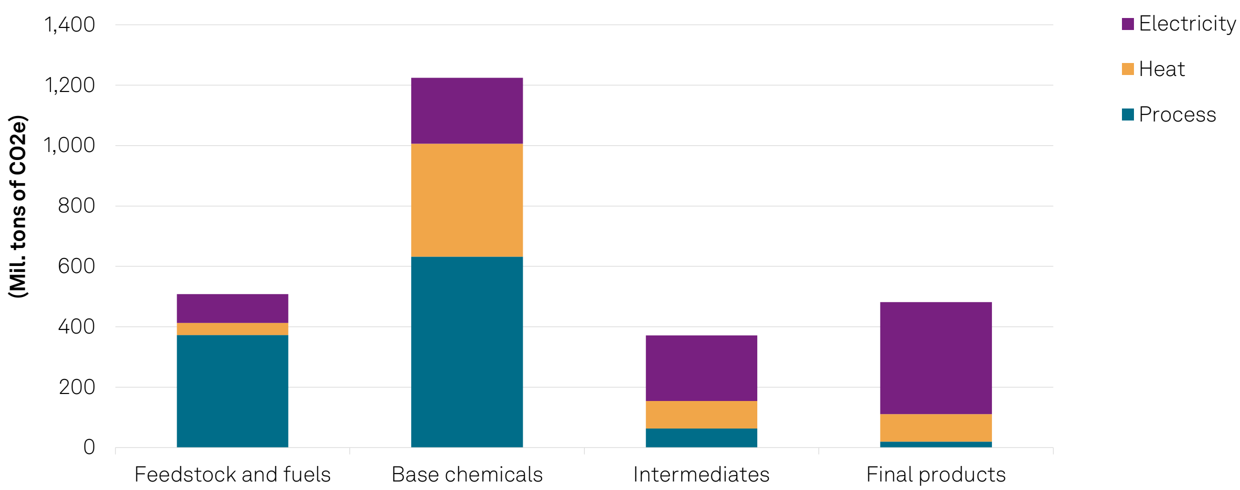
Feedstock/Fuels	Base chemicals	Intermediates	Final products *
Natural gas	**Ammonia**	PET	Specialty chemicals
Petroleum	**Nitric acid**	Polyethylene	Polymers, plastics
Coal	**Methanol**	Polyvinylchloride	Industrial chemicals
	Olefins	Styrene	Electronic chemicals
	Ethylene	Acetone	Adhesives/sealants
	Propylene	Phenol	Cosmetics materials
	Butadiene	Butanol	Flavorings, fragrances
	Aromatics	Ethylhexanol	Food additives
	Benzene	Acrylonitrile	Inks, dyes, printing chemicals
	Toluene	Polypropylene	Packaging, bottles, container
	Xylenes	MDI/TDI	Paints, coatings, resins
	Chlor-alkali	Cyclohexane	Polymer additives
	Chlorine	Ethylene oxide	Life science chemicals
	Sodium hydroxide	Propylene oxide	Surfactants, cleaning agents
	Sulfuric acid	Acrylic acid	Construction chemicals
		Methacrylic acid	Agrochemicals
		Acetic acid	Pharmaceutical drugs
		Formaldehyde	Water treatment chemicals

*Non-exhaustive list. Note: for clarity, table does not include non-fossil feedstocks: industrial gases (hydrogen, nitrogen, oxygen), sulfur, or brine for example. Source: S&P Global Ratings.

Emissions from base chemicals manufacturing are mainly from direct process emissions (see chart 4). Process emissions are linked to greenhouse gases generated as a by-product of the chemical reaction. Significant carbon dioxide is released by methane steam reforming to produce ammonia from hydrogen, and nitrous oxide forms during the production of nitric acid. Ammonia and nitrous oxide are important base chemicals that are combined to form ammonia-based fertilizers used widely in agriculture. Electricity consumption represents about one third of total emissions for the chemical sector, contributing more the further one goes along the production chain. Heat-related emissions represent one quarter of total emissions and are also largely concentrated on base chemicals, including for cracking which requires very high temperatures (around 800 degrees Celsius [°C]), and which may be hard to electrify. Yet a large share of the heating process in the sector is achieved at lower temperatures, which can therefore switch to (green) electric power. For instance, the IEA estimates that nearly 60% of the required process heat is below 150°C (as we discuss further in Decarbonizing Chemicals Part Two; chart 6).

Chart 4

Chemicals CO2 emissions across the product chain and by source

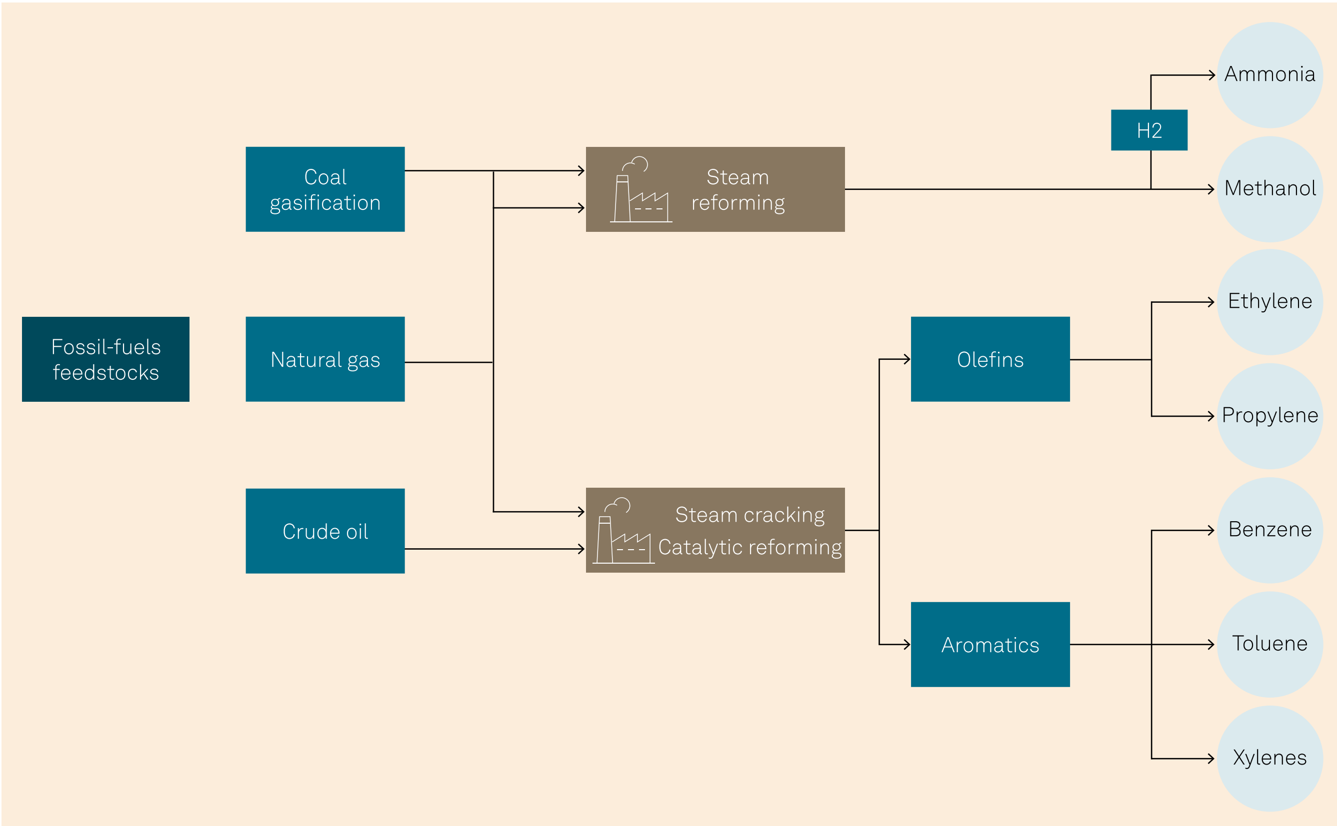


Source: Plastic Europe Eco-Profiles, S&P Global Ratings.

Focusing only on the most CO2 intensive areas within the chemical sector, chart 5 shows a simplified overview of the processes leading to the key base chemicals' standing as building blocks for the sector. The most intensive processes—steam cracking, methane steam reforming, and coal gasification—are at the core of the conventional petrochemical industry, with base chemical production involving process emissions and a heavy reliance on heat (note: the other base chemicals cited above—nitric acid, sulfuric acid, and chloralkali—are excluded because of their different manufacturing processes). Certain chemical players concentrate on a few product groups along the product chain, making them dependent on their upstream chemical suppliers and their downstream customers. A few large chemical companies are integrated into both upstream operations and into their downstream applications—this is known as the Verbund concept, and defines large integrated chemical plants. Additional complexity comes from the various production routes to arrive at a similar molecule.

Chart 5

Simplified hydrocarbon-based production routes for key base chemicals

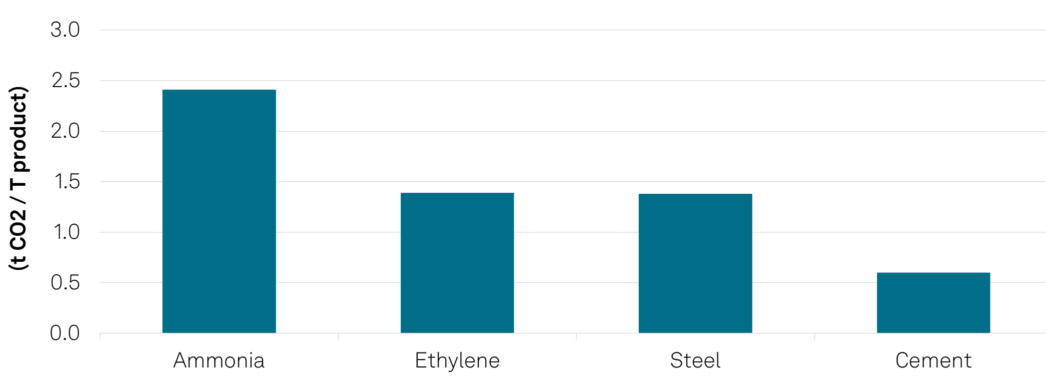


Source: S&P Global Ratings.

The carbon intensity of ammonia and ethylene specifically (two key base chemicals), is either on par with, or a multiple of, the other two highest industrial emitters, steel and cement production. For key base chemicals, the IEA estimates an average greenhouse gas intensity of about 1.3 metric ton of CO2 per ton of primary chemicals produced (see chart 6). This reflects the challenges of decarbonizing the chemical sector.

Chart 6

CO2 emissions intensity by product



Source: IEA, S&P Global Ratings.

Decarbonization Calls For A Broad Range Of Technologies

The chemical sector is exploring decarbonization solutions ranging from immediate energy efficiency measures to more ambitious long-term changes to feedstocks and fuels. Companies will deploy solutions according to their specific production processes, products, and localities. There is currently no clear consensus on the level of emissions that will be addressed through each of the available decarbonization solutions. The IEA, IRENA, and the United States Department of Energy have differing views on the contributions available technologies will make to emissions reductions. We therefore have more limited certainty and visibility on the long-term decarbonization capabilities of our rated companies, particularly beyond 2030, and the potential operational and financial implications at that time. In this section we explore the main technologies we think are relevant for companies in the chemical sector, summarized in table 2.

Table 2

Key decarbonization solutions feasibility and impact analysis

Likely implementation horizon

Short term	Medium term	Long term

Decarbonization technologies	Application	Scope	Development stage§	Disruptive level	Estimated cost	Impact
Energy efficiency	All processes	All processes	Adoption	Low	Low	Embedded in interim CO2 reduction targets at reasonable cost ≈ one third of total footprint
Electric power	Renewables sourcing*	All processes	Demonstration	Low	Moderate	
	Electrification	Non-intensive processes	Demonstration	Moderate	Moderate	
		Steam cracking	R&D	High	High	Unlikely to achieve net zero on olefins
Low carbon fuel/feedstock	Blue hydrogen > Ammonia	Steam reforming	Demonstration	Moderate	Moderate	Potential 70% reduction CO2 on ammonia (fertilizers)
	Green hydrogen* > Ammonia		R&D	High	High	Potential 90% reduction CO2 on ammonia (fertilizers)
	Hydrogen* as fuel	Steam cracking	R&D	Moderate	Moderate	Potential 75%-80% CO2 reduction on ethylene (olefin)
	Hydrogen* + CO2 > methanol-to-olefins		R&D	High	High	Potential net zero with CO2 management infrastructure
Carbon capture	CCUS	Steam cracking and reforming	Demonstration	Moderate	High	Likely in conjunction with CO2 management infrastructure

*On sufficient supply of renewable based electricity. §Scale: R&D > Demonstration > Adoption. R&D--Research and development. CCUS--Carbon Capture, Use and Storage. Source: S&P Global Ratings.

Energy efficiency

Optimizations of energy efficiency in chemicals manufacturing stand as low-hanging fruits for immediate action. Energy efficiency is widely adopted in most industrial players' operational strategies, including from a pure cost perspective. Recent spikes in energy prices have galvanized efforts, as has the threat of natural gas supply shortages in Europe. Energy efficiency has become a converging point for the sustainability of companies' business models, both for controlling costs and for reducing carbon footprints. We estimate that run-rate annualized energy savings could represent a 5%-10% reduction in greenhouse gas emissions for the sector, notably in chemical parks that share infrastructure and can better integrate with power providers, leverage waste heat sources, and minimize losses. While some of these can be achieved more imminently with a modest capital outlay—for example, with better digitalization and circularity management within a given chemical plant—some projects will involve optimization technologies such as high temperature heat pumps, or mechanical vapor recompression systems to recycle waste heat. In our view, the biggest efficiency savings are likely to involve a broader rethinking of utilities management in chemical parks, which will bring associated design complexity.

Electric power

When looking at electricity as a decarbonization solution, we distinguish between switching to renewables for already-electrified processes, and the new electrification of processes, which has varying levels of technical feasibility.

Renewables sourcing: We believe most industry players could switch to sourcing their electricity from renewable power at absorbable costs. This could reduce the sector's greenhouse gas emissions by one-third by the stated interim targets (around 2030), that is, about the share of already-electrified processes in the sector (see chart 4). Together with the above-mentioned efficiency gains, we believe the switch to renewables and the electrification of non-intensive processes are the main measures to achieve *interim* CO2 reduction targets in the sector. The industry's reliance on electricity is largely related to downstream products but also to some chloralkali (base chemicals; see table 1) manufacturing through the electrolysis of brine. We estimate that a significant portion of this production could be switched to low carbon or renewable electricity. That said, the cost competitiveness and availability of renewable electricity will ultimately depend on the scale of installed capacity. The intermittence of renewable energies could complicate the continuous power demands of commodity chemicals' processes. We expect that renewable energy sources would be backed by complementary conventional electricity or by adequate energy storage solutions. Intermittence across renewables—hydroelectric, solar thermal, photovoltaic, wind, biogas or biomass-based—varies. We also expect to see more power purchase agreements (PPAs) across the sector, to secure renewable sourcing and appropriately mitigate cost volatility, notably for stable electricity off-takers (see "EU's Proposed Energy Market Redesign Mitigates Merchant Risks And Accelerates Renewables," published April 3, 2023). Chemical players are securing renewable energy procurement as part of their current decarbonization strategies. For example, Austria-based petrochemical company Borealis targets 100% of renewable electricity for its polyolefins and hydrocarbons business by 2030, while BASF targets 60% at group level by then.

Electrification: Among most intensive chemicals processes, we view partial electrification of crackers as realistic. We nonetheless think emissions from the most energy-intensive processes such as steam cracking, methane reforming, and coal gasification (see chart 5) will be much more difficult to abate. These processes either have high process emissions or involve chemical reactions that require very high temperatures. They produce many of the building blocks essential to downstream production chains.

- We estimate that steam cracking to produce olefins and aromatics (base chemicals, see table 1) represents 10%-15% of the sector's total greenhouse gas footprint, of which around a quarter relates to heating. While achieving 800°C using electricity will be difficult, we understand the separation and compression steps—which can represent about half of the energy consumed in cracking—have the potential be electrified today based on current research and development. We understand that temperature requirements could for instance be lowered using catalysts, as is currently the case for aromatics (through catalytic reforming), but we also understand this approach requires further innovation to reach commercial viability for olefins. Therefore, we think further CO2 abatement will involve alternative fuels/feedstocks to the current hydrocarbons. Accordingly, table 3 provides tangible examples of cracker decarbonization investments some of our rated companies have announced.
- We believe the high temperatures needed for coal gasification, and its process CO2 emissions, make electrification irrelevant. We estimate that this process, which has opportunistically exploited locally available coal as an alternative to conventional petrochemistry, offers limited solutions for decarbonization and ultimately might be phased-out on a long-term pathway to net zero.
- Steam methane reforming for hydrogen production, largely serving ammonia manufacturing (as a key base chemical for fertilizers), likewise will not be electrified per se because most of the emissions are process CO2 releases. Prevailing technologies to produce low-carbon hydrogen therefore concentrate on carbon capture and water electrolysis, which we explore further below.

Table 3

Examples of chemical companies' strategies to reduce cracking emissions

Company	Project
Borealis	Cracker of the future. The consortium includes Repsol, Versalis (Eni), BP, and TotalEnergies, or about one third of the EU's steam-cracking capacity. The project involves bio-naphtha in feedstock, cracker electrification, and looping back recycled materials in the cracker via a waste plastic pyrolysis process.
BASF, SABIC and Linde	A joint agreement to develop electrically-heated steam-cracker furnaces. The project claims that it will reduce the CO2 footprint of the process by 90%.
Ineos	€4 billion investment in Project One. This is one of the industry's largest investments in decades in the EU, to build one of the most efficient and sustainable crackers in Europe targeting a net-zero footprint, including a fully hydrogen-fired-ready plant.
The Dow Chemicals Company	Retrofit of its ethylene and polyethylene production plant in Fort Saskatchewan, Alberta. This project started in 2021 and aims to triple the plant's capacity while achieving net zero scopes 1 and 2 CO2 emissions. The company expects to spend $1 billion per year on the project, and enter into production by 2030, thereby decarbonizing about 20% of the group's total ethylene capacities. It will also convert cracker off-gas into hydrogen as clean fuel for the production process, together with captured CO2 to be managed by third-party infrastructure. The company's roadmap targets 60% of its sites to be hydrogen-ready by 2040.

Source: Companies' websites.

Low carbon fuel/feedstock

In the likely scenario where efficiency gains and reliance on electricity cannot further abate the sector's CO2 emissions beyond our rated companies' interim targets, the industry might consider alternative fuels and feedstocks. Our rated companies' stated strategies include bio-based feedstocks and fuels, the supply of which is constrained by land availability to source bio-based materials, and by the lack of storage and transport infrastructure. Recycled fuels and feedstocks offer the dual benefit of addressing CO2 emissions reductions by avoiding using virgin materials in production, and tackling plastic waste in the environment. While this is a challenging issue for the sector, we do not investigate in this research issues linked to plastics collection and recycling. We believe medium-term decarbonization will rely on a mix of bio-based and recycled feedstocks, at least temporarily, depending on plant-readiness and inputs availability. We also think that hydrogen as alternative fuel and feedstock may offer a combination of benefits across the sector over the longer term.

Blue and green hydrogen will be key to decarbonizing ammonia-based fertilizers. Ammonia (key base chemical; table 1) currently consumes about 50% of globally available hydrogen, and 70% of ammonia produced is used for nitrogen-based fertilizers. Today's hydrogen is largely derived from steam methane reforming (SMR), generating considerable carbon dioxide as a direct by product—which gives ammonia its very high emissions intensity (chart 1). As a result, we see a role for cleaner hydrogen production:

- **Blue hydrogen** uses the same SMR process from natural gas and carbon capture and storage, to produce "blue" ammonia (example table 4).
- **Green hydrogen** relies on water electrolysis thereby avoiding CO2 release but consuming more energy than SMR. As renewable electricity production scales up, electrolyzers could become more affordable, but are still likely to involve large capital outlays. Still, we estimate that green hydrogen can reduce ammonia's CO2 footprint by about 90% versus the conventional Haber-Bosch process. This, in turn, could reduce fertilizers' footprint by about 80%-90%, which could be important for reducing agricultural sector emissions.

Table 4

Examples of fertilizers decarbonization using blue and green hydrogen gaining momentum in the U.S. supported by the U.S. Inflation Reduction Act

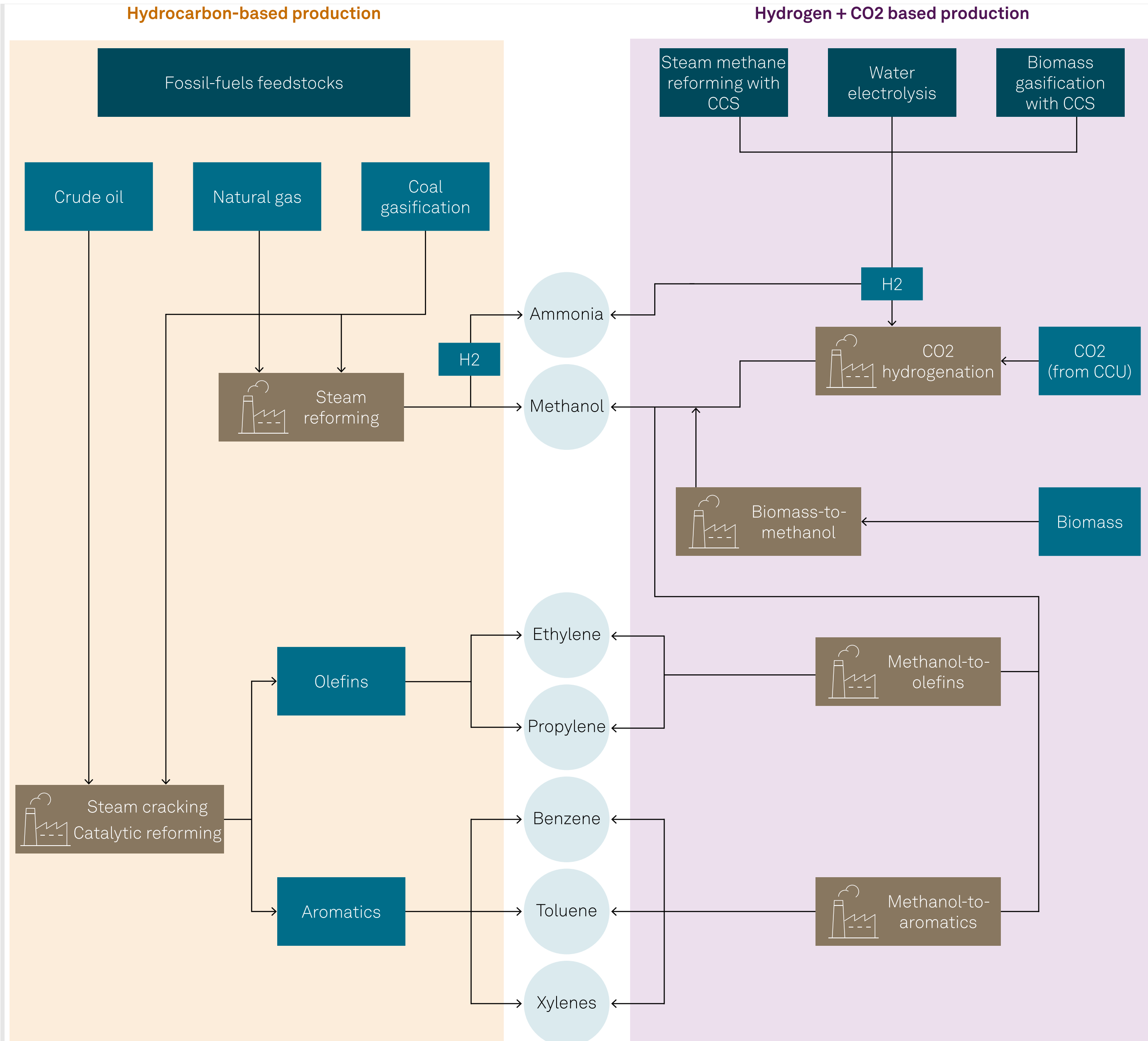
Company	Project
OCI Global	Fertilizer producer OCI is developing a blue ammonia project using hydrogen from Linde and third-party carbon capture. This represents a $1.8 billion investment of which $1.0 billion comes from OCI Global itself. OCI expects to reduce the ammonia plant's carbon dioxide footprint by 70% on a life-cycle basis compared to conventional processes.
CF Industries	CF Industries started a green ammonia project at its Donaldsonville, Louisiana, complex in 2021, which will use electrolysis to generate carbon-free hydrogen from water. It will produce about 20,000 metric tons of green ammonia annually. The company also signed a deal with Mitsui & Co in 2023 for a $2 billion blue ammonia project at the same complex. This project is based on capture involving a $200 million investment in carbon dioxide compression and a dehydration unit.
Yara International ASA	Fertilizer producer Yara has established Yara Clean Ammonia (YCA) as a separate unit that is a potential candidate for an IPO in the coming years. In addition to Yara’s blue and green ammonia projects in Norway, the Netherlands, and Australia, YCA has signed several partnerships including with Enbridge and BASF on the U.S. Gulf Coast for blue ammonia, with expected 95% carbon dioxide capture. YCA has also sealed an agreement with power producer CEPSA to provide up to 750,000 tons of green ammonia in Europe, consolidating 2 gigawatts of electrolysis capacity in the Andalusian Green Hydrogen Valley.

Hydrogen could be an efficient alternative fuel for heating steam crackers. As is developing in the steel industry, low carbon hydrogen as a combustion fuel could address a material portion of heat-related and process emissions in petrochemicals steam cracking to produce olefins. This is because the combustion of hydrogen essentially produces water or steam. We note Ineos and Dow Chemicals' major investments in fitting their plants for hydrogen (see table 3). Key challenges include the availability and cost of low carbon hydrogen, which in turn depends on the availability of renewable power. In addition, fuel switching doesn't address the carbon content of the feedstock—extraction, process-related, or life-cycle CO2 emissions linked with chemical products would still remain.

Hydrogen and CO2-based chemistry could also be key to decarbonizing methanol and olefins. Currently, methanol (key base chemical; table 1) production still largely depends on high-emitting coal gasification, widely used in Asia. It is still a secondary product used to produce formaldehyde and alternative fuels. However, 30% of available methanol is currently used to produce olefins at industrial scale. This process—methanol-to-olefins—has traditionally leveraged locally available coal to by-pass conventional cracking of olefins. As such, methanol stands as a pivot point between coal-based chemistry and conventional oil-based chemistry. However, methanol can also be obtained using hydrogen and captured CO2 as feedstocks. This alternative approach could offtake CO2 captured from other processes such as SMR, steel, and cement production. The option to obtain methanol from low-carbon hydrogen and CO2—both as feedstocks—may open an alternative, low-carbon route to olefins and aromatics versus traditional fossil-based petrochemical cracking (chart 7). While such developments would represent a significant change to the conventional industry structure, we currently view it as remote or long-term given the implied huge investments in clean hydrogen scale-up and CO2 management infrastructure.

Chart 7

Comparing hydrocarbon-based with hydrogen + CO2 based chemicals production routes



CCU--Carbon capture and utilization. Source: S&P Global Ratings, CellPress One Earth.

Hydrogen, ammonia, and methanol are also gaining traction as energy carriers. Hydrogen has attracted considerable attention in recent years as a potential alternative fuel to hydrocarbons. While hydrogen could be used in steel manufacturing or heavy ground transportation, the high energy needed for clean hydrogen production raises its own issues. Its storage and transportation also present challenges given its very low density and its explosive and corrosive nature. Some of the largest entities involved in this segment, such as Linde PLC, Air Liquide S.A., and Air Products and Chemicals, Inc., are increasingly investing in growing their blue and green hydrogen capacities. They are also developing their carbon dioxide management by building carbon capture capacities for their own use and to sell to high-emitting customers, while delegating the related storage and use to third parties. Ammonia and methanol are being talked about as potentially more convenient energy carriers than hydrogen. They are safer and easier to transport and have higher energy density. Similar to industrial gases, some fertilizer companies are taking steps toward developing ammonia and methanol as potential fuels, for example as maritime fuel, for which demand is increasing exponentially. Many fertilizer companies have embedded a hydrogen-based transition as core to their strategies and are calling for supporting regulation and infrastructure developments.

Carbon capture use and storage

Carbon capture, utilization, and storage could help decarbonize the chemical sector by cutting down emissions but also by being harnessed as a feedstock. We believe that direct carbon dioxide capture from chemical processes could address emissions from hydrocarbon-based chemistry that cannot be addressed by efficiency gains or electrification. CCUS is likely to add costs to companies' production processes via increased capital spending and energy use, but could potentially offset some costs if carbon dioxide is used as a feedstock for other processes, such as methanol. The IEA estimates the cost of carbon capture at $15-$35 per metric ton from ethylene, ammonia, or coal-to-chemicals processes, and $50-$80 per metric ton from hydrogen SMR. Key to the cost of carbon capture is the concentration of carbon dioxide in off-gas, which tends to be relatively high in primary chemicals production. This concentration could make CCUS economically more viable for the chemicals industry. However, alternative chemical routes such as clean methanol-to-olefins (based on carbon dioxide as a feedstock) would require large volumes of carbon dioxide, on current capacity needs, for olefins and aromatics. This approach would also need high associated capital outlays for capture installations and management infrastructure.

We see the sector's use of carbon dioxide removal (CDR) and direct air capture (DAC) as remaining very limited. Some companies are exploring CDR methods, such as afforestation, or DAC (see "Carbon Capture, Removal, And Credits Pose Challenges For Companies," published June 8, 2023) as part of their broader decarbonization strategy. While these methods do not directly reduce emissions from existing sources, some companies are investing in their use to support "net" emissions reductions claims. Given the volume of emissions in the sector, CDR and DAC introduce key risks such as competition for land for afforestation. DAC is also highly energy intensive and expensive.

Carbon Regulations Remain Manageable For Now

The pace and costs associated with decarbonization of the chemical sector will be influenced by how policy and regulation evolve. This evolution will vary depending on geography and jurisdiction. A disordered regulation on the chemical sector, which is largely globalized, could influence our rated companies' competitiveness, and pose equal threats of disruptions. We discuss the potential cost impacts of such regulation in "Decarbonizing Chemicals Part Two: The Credit Risks and Mitigants".

Regulation in the EU focuses on carbon pricing

The EU aims to hasten the adoption of technology and operational initiatives that reduce emissions. The EU also wants to use pricing to encourage consumers toward lower-carbon alternatives. This approach mirrors its playbook in other sectors. The European Economic Area as well as the U.K. and Switzerland face the highest costs. The European Green Deal aims for less than 1.5°C global warming by 2100 and has also raised its 2030 target to at least 55% emissions reduction (versus 1990 levels). A key action will be to tighten annual EU Emissions Trading System (EU ETS) caps and reduce the supply of free carbon allowances.

The rising cost of carbon emissions under the EU ETS has become ever more relevant for European companies. Allowances have reached record highs of €90/metric ton from an average of below €10/metric ton over the decade before 2020. But this may not yet be enough to lead the energy transition, in our view. Many industrials, including chemical players, have benefited from the free allowances that have limited the cost effects of the energy transition. EU emissions allowances are expected to reduce by about 2.2% per year between 2020-2030. This will likely cause carbon costs for chemical companies to increase and may encourage them to further invest in long-term decarbonization technologies.

The gradual introduction of the Carbon Border Adjustment Mechanism (CBAM) will spread the impact of carbon regulation beyond the EU. The aim of CBAM is to prevent "carbon leakage"—the moving of carbon-intensive production abroad to less-strict jurisdictions or the replacement of EU products with more carbon-intensive but economically competitive imports. CBAM will initially focus on the cement, steel, aluminum, fertilizers, electricity, and hydrogen sectors. It will increase the export costs of related chemical products for non-EU manufacturers, encouraging them to reduce carbon emissions, while maintaining the competitiveness of EU-based producers. We expect CBAM to start affecting companies' trading profiles after 2025, when most will have consumed their stocks of EU ETS allowances and mandatory carbon reporting under CBAM is imposed. Companies will be tested on their ability to pass higher carbon costs on to end-users, and on their ability to reduce their carbon footprint by then. We expect the price of CBAM certificates could rise significantly as the supply decreases.

Producers of fertilizers will likely face additional regulatory pressure. Given the volume of emissions across the fertilizer production chain—from the production of hydrogen (SMR/ATR), ammonia, nitric acid, and sulfuric acid—companies face significant exposure to carbon costs. After-application scope 3 emissions, whereby nitrous oxide is released into the atmosphere from nitrogen-based fertilizers, could attract additional costs and regulatory burdens. This could in turn result in reduced demand from the agricultural sector. While nitrogen is a key nutrient for crops, it commonly raises questions about farming practices, excessive use of fertilizers, and the need for more granular crops and just-in-time management as well as nitrification inhibitors. Crop management practices are in turn constrained by farmers' co-ops, which require harvests to have certain levels of protein content, which in turn encourages nitrogen use. Food demand is also a key driver for increasing crop yields. Solutions may therefore be found on the regulatory side. The EU Green Deal targets a 20% reduction in the use of fertilizers by 2030, while increasing yields by 30% to sustain demand growth, and growing organic farming to 25% from around 10% currently. These goals present challenges around land use, potential volume trends for fertilizer companies, and price/cost-spread management where there is no substitute for nitrogen-based fertilizers.

Incentives-based regulation prevails in the U.S.

The U.S., by contrast, has adopted a more incentives-based approach to encourage investment in low-carbon solutions, which could potentially benefit chemical companies. The U.S. Inflation Reduction Act (IRA) provides subsidies for a range of low-carbon technologies that could increase the economic viability of renewable deployment, CCS, and other related technologies. This could also lighten U.S. chemical companies' costs of—and capital allocation associated with—decarbonization strategies, potentially encouraging an increase in decarbonization activity.

In our view, the IRA will also likely increase the costs of the main sources of feedstock and fuel for the chemical sector. The IRA increases royalties paid by the oil and gas sector and introduces methane mitigation fees. It also features new and extended tax credits that aim to encourage businesses and individuals to boost their use of renewable energy. Although still unclear in magnitude, the Act could weigh on the financial ratios of several U.S.-based chemical companies and refiners (see "U.S. Inflation Reduction Act Highlights Diverging Approaches With Europe," published March 1, 2023), but could encourage some to explore the increased use of alternative feedstocks, although this will be limited by the ability to integrate their use into existing processes.

Looking Ahead

The decarbonization of the chemical sector implies a combination of technologies and processes, and perhaps no consensus will be reached on the most appropriate path to net zero. Our research "Decarbonizing Chemicals Part Two: The Credit Risks and Mitigants" analyzes the credit implications of solutions currently available to our rated issuers to achieve their decarbonization targets, and eventually what could be the impacts on our credit analysis. We understand that a portion of greenhouse gas emissions will be addressed by efficiency measures, electrification, and the switch to renewables. In our view, companies can implement these measures without materially disrupting their cost structures by allocating capital in a disciplined manner through to 2030.

However, a significant proportion of emissions—including from the most emissive cracking, reforming, and gasification processes—will involve the longer-term rethinking of current production chains. Hydrogen-based chemistry and alternative routes to olefins and aromatics could be part of this picture. Because these technologies and their supply chains require more research and development, we expect to see the impact of these changes on industry cost structures and market strategies more clearly beyond 2030. We also expect regulatory constraints and incentives will move at a pace that supports the sector and wider decarbonization targets.

Related Research

- Decarbonizing Chemicals Part Two: The Credit Risks And Mitigants, Sept. 5, 2023
- Carbon Capture, Removal, And Credits Pose Challenges For Companies, June 8, 2023
- U.S. Inflation Reduction Act Highlights Diverging Approaches With Europe, March 1, 2023
- EU's Proposed Energy Market Redesign Mitigates Merchant Risks And Accelerates Renewables, April 3, 2023
- Decarbonizing Cement Part One: How EU Cement Makers Are Reducing Emissions While Building Business Resilience, Oct. 27, 2022
- Chemical Economics Handbook, S&P Global, Commodity Insights, 2023
- Petrochemical Industry Overview, S&P Global Commodity Insights, Sept. 15, 2022

External Research

- Chemicals sector profile, International Energy Agency
- Ammonia technology roadmap, International Energy Agency, October 2021
- The Future of Hydrogen: Seizing Today's Opportunities, 2019, International Energy Agency
- 2023 Facts and Figures of the European Chemical Industry -Environmental Performance, The European Chemical Industry Council
- 2021 ICCA Responsible Care Leadership Group Status Report, International Council of Chemical Associations
- Sustainability footprints of a renewable carbon transition for the petrochemical sector within planetary boundaries, One Earth article, CellPress, April 2021
- Electrification of the chemical industry—materials innovations for a lower carbon future, Eryazici, I., Ramesh, N. & Villa, Materials Research Society Bulletin, 2021
- Decarbonizing the chemical Industry, McKinsey, 2023
- Eco-profiles for determining environmental impacts of plastics, Plastics Europe
- The Global Chemical Industry: Catalyzing Growth and Addressing Our World's Sustainability Challenges, Oxford Economics, 2019,
- Project One, Ineos
- Accelerating electrification with the "Cracker of the Future" Consortium, Sept. 9, 2021
- BASF, Joint News Release, "BASF, SABIC and Linde join forces to realize the world's first electrically heated steam cracker furnace, March 24, 2021
- OCI to Start Construction of New World-Scale Hydrogen-Based Blue Ammonia Facility in Texas with Production Expected in Q1 2025, Sept. 8, 2022

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