Sectoral Risk Briefings:
Insights for Financial Institutions

UN environment programme

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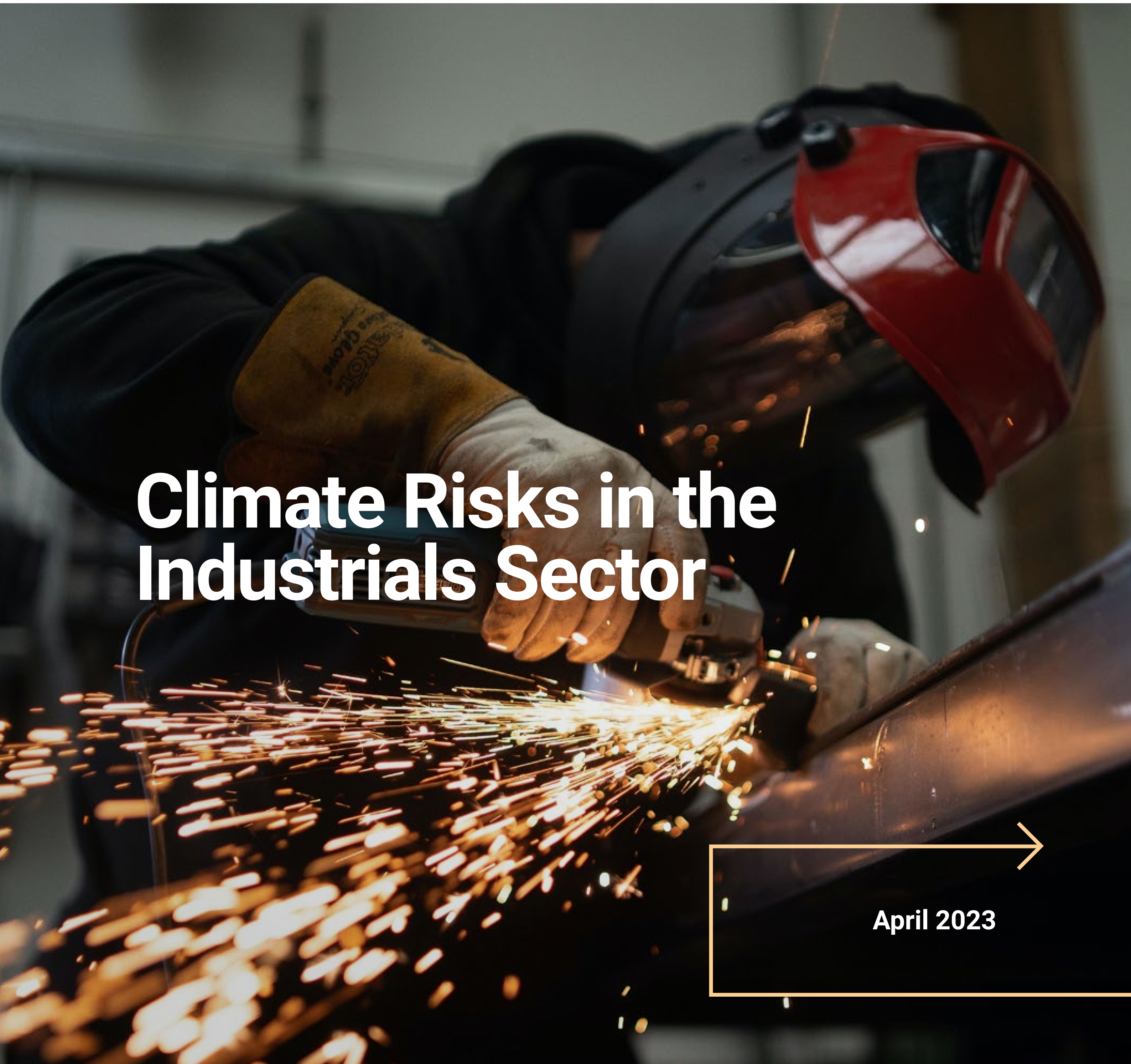

Climate Risks in the Industrials Sector

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Acknowledgments

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Introduction

In the past few years, the global economy has been lashed by the COVID-19 pandemic, geopolitical conflict, supply chain disruptions, an energy crisis, and high inflation. These challenges are occurring against the backdrop of the mounting planetary emergency of climate change. Climate change can exacerbate all other challenges, increasing geopolitical conflicts over resources, crippling infrastructure and supply chains, extending the range of dangerous pathogens, and collapsing the natural systems upon which we depend. As the US Pentagon presciently stated: "climate change is a threat multiplier". While the transition to a sustainable, net-zero future is critical, it demands fundamental shifts in nearly all economic sectors. These shifts are not without risk for companies and communities impacted by them.

Financial institutions face an array of risks from this rapidly changing, and often chaotic, world. Their clients are exposed to physical hazards as well as transition risks, which can have major credit, market, and operational implications. The prudent financial institution will explore these climate-related risks and prepare strategies to meet them. Future resiliency and success are contingent on thoughtful planning and good decisions today.

UNEP FI has been working at the intersection of sustainability and finance for over 30 years. Its programmes for financial institutions develop the tools and practices necessary to positively address the most pressing environmental challenges of our time. UNEP FI's Climate Risk and TCFD Programme has now worked with over 100 financial institutions to explore physical and transition risks posed by climate change. Through this work, a need has been identified to provide financial institutions with a baseline understanding of climate-related risks and their manifestations across different sectors.

This brief is part of a series of notes that cover major economic sectors and their associated climate risks. Each brief also provides specific guidance and recommendations for financial institutions to more effectively manage their risks and those of their clients.

UNEP FI intends for the resources and perspectives included within these notes to empower financial colleagues to communicate these risks throughout their institutions and across the financial sector more generally. The hope is that the communication process will not only enhance awareness of climate risks, but will also begin conversations that will lead to tangible changes in strategy and operations. It is the integration of the insights that will be the truest test of the effectiveness of this series. This particular brief covers the physical and transition risks facing the industrials sector.

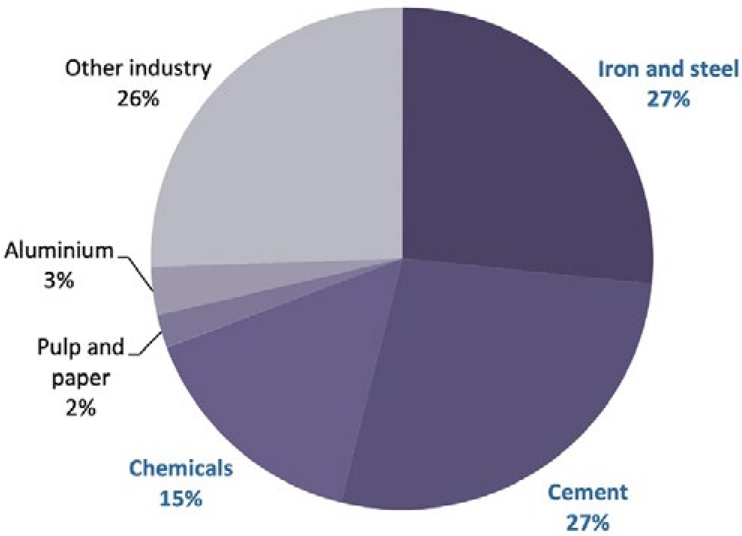
Industrials overview

The industrials sector accounts for 25% of global carbon dioxide (CO_2) emissions (IEA, 2022b). It comprises many sub-sectors, including manufacturing, petrochemicals, steel and iron, and construction inputs. The share of industrials sub-sectors in emitting global CO_2 emissions is shown in Figure 1. As the global economy accelerates its efforts to meet the goal of net-zero emissions by 2050, the carbon-intensive industrials sector will have a crucial role in decarbonising the global economy.

Table 1: Industrial sub-sectors categorisation used in this report

Sub-sector	Definition
Steel	All steel production
Other Metals	Iron, aluminium, brass, copper, etc.
Petroleum and chemicals	Including ammonia for fertilisers, polyamides (PA), nitric acid, etc.
Pharmaceuticals	All pharmaceutical production
Plastics	Polyethene (PE), polystyrene (PS), polyurethane (PU), PA, etc.
Wood processing	Paper, pulp, wood
Cement and construction inputs	Cement, concrete, lime
Machinery and electronics	Machinery and technology, i.e. semiconductors, aerospace technology, automotive equipment, etc.
Other	Including glass, textile, garment, food and beverage processing, etc.

Figure 1: Share of global direct CO_2 emissions by industry sub-sector (CSIS, 2020)



In the modern economy, cement is the second most consumed material globally after water (WEF, 2022a). Cement manufacturing is one of the most emissions-intensive commercial operations in the world, accounting for 7% of global CO_2 emissions (GCCA, 2021). Iron and steel production represent 11% of CO_2 emissions (Carbon Brief, 2021), with steel representing over 90% of metals produced globally (CDP, 2019a). The plastics industry produced 850 million metric tons of greenhouse gases (GHGs) in 2019. Plastic production accounts for 3.4% of total CO_2 equivalent (CO_2e) emissions (OECD, 2019). Ammonia is the second-most widely produced chemical commodity. It is mainly used as fertilizer in agriculture (Argus, 2021). Ammonia synthesis produces approximately 500 million tons of CO_2, accounting for 1.8% of global CO_2 emissions (The Royal Society, 2020).

Many industrials sub-sectors rely on activities that are hard to decarbonise. For example, the production processes of both petrochemicals and cement require large amounts of heat (IEA, 2018a). Additionally, CO_2 is a byproduct of many industrial production methods, most notably in the production of ammonia and clinker (an intermediate product used in cement manufacturing) (Kleinman Energy, 2021). High emissions are mostly generated through fuel combustion for high-temperature generation and manufacturing processes. As the world decarbonizes, steel, cement, plastics, and ammonia production will face substantial transition risks. The industrials sector overall faces growing policy pressures as governments increasingly implement carbon prices that cover emissions generated by the sector. Operational advances and technological innovations will also reduce the market shares of conventional producers with less carbon-intensive alternatives. As awareness of climate change grows, industrial firms are also at risk of legal and reputational damages.

The industrials sector often relies on stable climate conditions to enable effective operations in complex supply chains. As extreme weather events increase in frequency and severity, the physical impacts of climate change will make current industrial practices more difficult or risky. Exposure of the industrials sector to physical risks emphasises the need to prioritise climate action. Below we explore in depth the key physical and transition risks faced by the industrials sector (Table 2).

Table 2: Key climate risks for the industrials sector

	Risk	Summary
Transition Risks	**Increasing carbon price**	High emitters in the industrials sector, such as cement and steel, will be negatively impacted by carbon pricing, due to rising costs or reduced demand due to higher prices.
	Public policy restrictions	More stringent regulatory requirements for industrial facilities will increase environmental regulatory pressure to decarbonize and limit industrial pollution. For international producers, rules regulating the carbon intensity of imported industrial products will pose significant challenges.
	Technological shift and advancement of low-carbon technologies	Technological advances in low-carbon alternatives, along with rising carbon prices and other regulatory restrictions, will drive a shift from conventional industrial products to low-carbon alternatives.
	Emerging legal risks	Multiple litigation cases have been filed against industrial companies in recent years for failing to comply with environmental regulations.
	Rise in reputational risk	Industrial sector companies will face reputational damage if they are too slow in responding to shifting demand patterns from consumers and shareholders for more sustainable inputs, production processes, and disclosures.
Physical Risks	**Intense storms and flooding disruptions**	Storms and flooding events will become more frequent and severe, increasing the risk of damage to production facilities and disruptions in supply chains.
	Droughts	Greater severity and frequency of droughts in specific geographies will negatively impact industrial sector companies with water-intensive manufacturing processes.
	Temperature increase	Higher average temperatures will impede worker productivity, hamper industrial cooling processes, and increase expenses for air conditioning.
	Wildfires	Wildfires threaten to damage industrial facilities, reduce the water supply for industrial operations, and create hazardous working conditions for employees.

SECTION 1:
Transition risks

The industrials sector contains many high emitting activities that are challenging to abate. The accelerating net-zero transition will pose significant policy and technological challenges to industrial firms. Carbon taxes will raise the costs of carbon-intensive cement, petrochemical, and concrete production and improve the economics for low-carbon competitors. High emission sub-sectors may also be exposed to increased litigation and reputational risks.

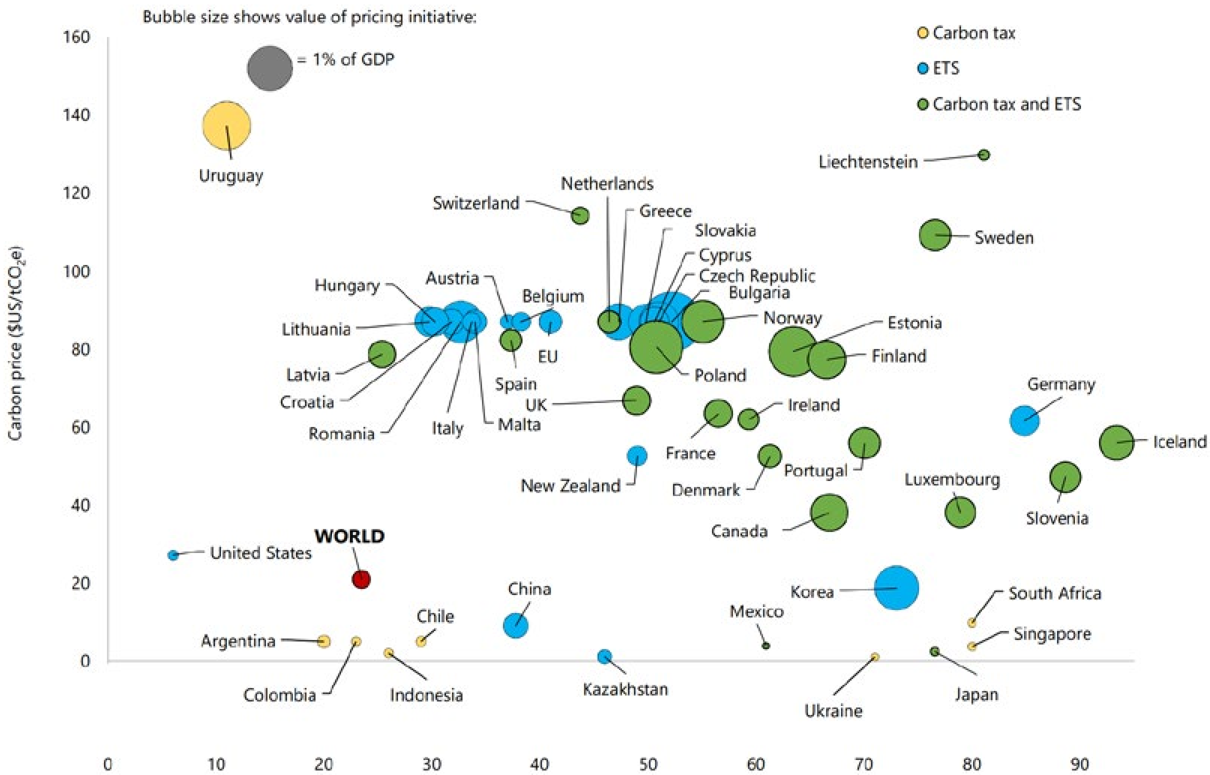
The transition risks facing the industrials sector also pose a risk for workers and communities that rely on the sector for jobs and income. It is therefore important to align financing with a just transition approach that considers the impact of the transition on groups at risk to operations in the industrials sector, including workers, Indigenous Peoples and local communities.

1. Increasing carbon price

Carbon pricing poses various risks to carbon-intensive sectors, such as the industrials sector and its sub-sectors. A carbon price is a charge on fossil fuels based on their carbon content or their emissions when burned (IMF, 2022a). Such schemes are expected to play a fundamental role in the low-carbon transition through direct carbon taxes, emissions trading systems (ETSs), or internal carbon pricing models used by corporations and financial analysts. According to Kepler Cheuvreux, an advisory and asset management company, a carbon price of over EUR30 per ton of CO_2 (tCO_2) could create “an existential threat for the viability of many [steel] producers” as high carbon prices cut into revenues and drive up costs (Kepler Cheuvreux, 2018).

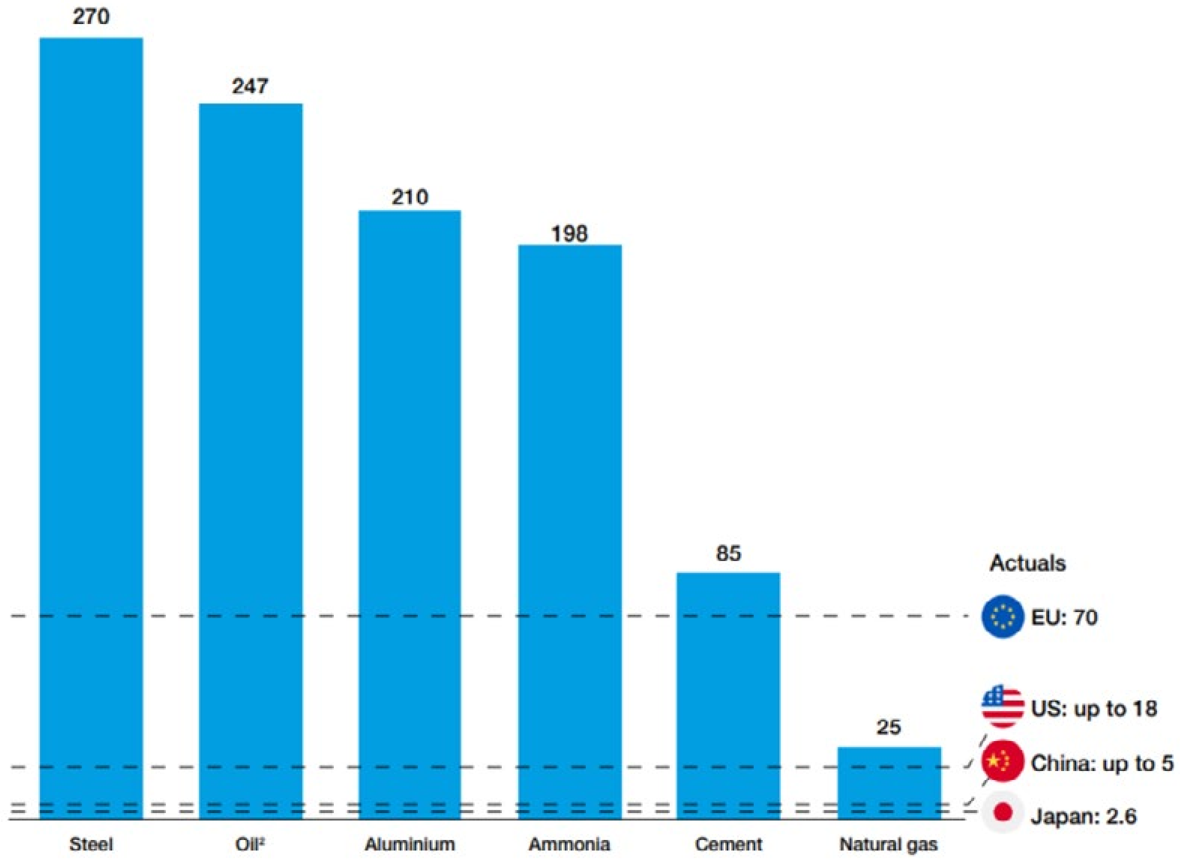
A carbon tax is typically implemented as a direct tax on the carbon content of fossil fuels, i.e. a price per ton of CO_2e (tCO_2e). ETSs require companies to obtain allowances for their emissions or the carbon content of the fossil fuels used. Under an ETS, governments are able to control the supply of these emission allowances and the trading of these allowances at a carbon price. The momentum for carbon pricing has been accelerating globally as a growing number of countries implement a carbon tax and ETSs. These range in coverage and price. Currently, 30 carbon taxes and nine ETSs have been implemented at a national level (Figure 2). These carbon prices vary from below US$5 to above US$100 per ton, and can cover 30–70% of GHG emissions in their schemes (IMF, 2022a). In 2020, China launched a national ETS. Once fully operational, it will incorporate seven major sectors by 2025: petrochemicals, chemicals, building materials, steel, nonferrous metals, paper, and domestic aviation. Together, these cover one-seventh of global CO_2 emissions from fossil-fuel combustion (IEA, 2020a). The EU launched its ETS launched in 2005. In 2017, the iron and steel emissions covered under the EU ETS substantially increased, while the ETS price rose by over 200% to EUR15/tCO_2. Due to market reforms, the ETS price in the EU is expected to rise to EUR20–50/tCO_2 by 2030 (Kepler Cheuvreux, 2018). In the first 14 years of the scheme, installations covered by it saw their emissions reduce by an average of about 35% (European Commission, n.d.). In 2019, the EU ETS was revised to include a Market Stability Reserve. The goal was to introduce higher and more robust carbon prices. At the time, these accounted for a reduction in the emissions of the industrials sector of 1.9% (European Commission, n.d.).

Figure 2: Subnational, national, and regional carbon pricing schemes ([IMF, 2022a](IMF, 2022a))



Currently, approximately 86% of steel production is covered by markets with carbon prices. Existing carbon prices are lower than the carbon prices needed to drive decarbonisation in the industrials sector, as shown in Figure 3. However, as an increasing number of countries set out net-zero targets, carbon prices are expected to rise. The World Economic Forum's (WEF) Net-Zero Industry Tracker 2022 has estimated the carbon price needed for industrial sub-sectors to reach net zero by 2050, as shown in Table 3. The US market intelligence firm S&P Global found that less carbon-intensive alternative solutions—such as green hydrogen and full-scale carbon capture—become financially viable for European steel, chemical, and cement manufacturing sub-sectors at carbon prices of EUR131 per ton or above (S&P Global, 2022a).

Figure 3: Carbon prices (US$/$tCO_2e$) needed to incentivise the development of low-emission production technology for industrial sub-sectors and Oil & Gas to reach net zero by 2050 (WEF, 2022a)



Notes: 1 Based on the estimated carbon price necessary to make "low-emission" product prices competitive with traditional product prices; 2 Refers to refined petroleum products.

Table 3: Estimated carbon price for industrial sub-sectors to reach net zero by 2050 (WEF, 2022a)

Industrial sub-sector	Carbon price (US$/$tCO_2e$)
Steel	180–360
Cement	60–110
Aluminum	210
Ammonia	36–360

High carbon prices can lead to higher costs and larger reductions in output and profits for heavy industry companies. A carbon price in the industrials sector will result in additional direct and indirect costs for businesses, impacting revenues and operating costs for firms. Direct impacts of a carbon price on businesses include tax costs related to fuel and energy used in production. The indirect effects of a carbon price on businesses are the costs incurred during the production processes due to the implementation of a carbon tax in earlier production stages. The emissions-intensive industrials sector is likely to incur high direct costs. Overall cost increases may still impact industries that are not directly subjected to carbon tax due to their reliance on inputs that use emissions-intensive production processes (EY, 2020). Figure 4 illustrates the potential impacts of a carbon tax of US$25/t$CO_2$ across manufacturing sub-industries in the United States. As industries depend on fuel inputs, they are likely to be impacted by changes in carbon-intensive fuel costs under a carbon price. Variability in fuel uses for sub-sectors will result in a carbon price impacting certain industries more than others. For example, the primary metal sub-industry is the most vulnerable to a carbon tax. A carbon tax of US$25/t$CO_2$, for instance, would hit it with an estimated increase in production costs of 2.2% (1.0% direct impact and 1.2% indirect impact). In comparison, under the same carbon tax, the production costs of the paper industry will rise by a projected 1.5%, with the indirect impact of the carbon tax being double the direct impact (EY, 2020).

The effect of carbon prices on the production costs of industrial sub-sectors is expected to increase as governments raise carbon prices. For example, Singapore has announced that it will put up its carbon price from US$18.1/t$CO_2$ (SG$25/t$CO_2$) in 2024 to US$58/tCO_2 (SG$80/t$CO_2$) by 2030. This will lead to an increase in power prices of between US$5/MWh (SG$7/MWh) to US$16/MWh (SG$22/MWh) (S&P Global, 2022b), which, in turn, will result in increased costs for industrial producers.

Figure 4: Impact of a carbon tax on industry production costs and consumer prices (EY, 2020)

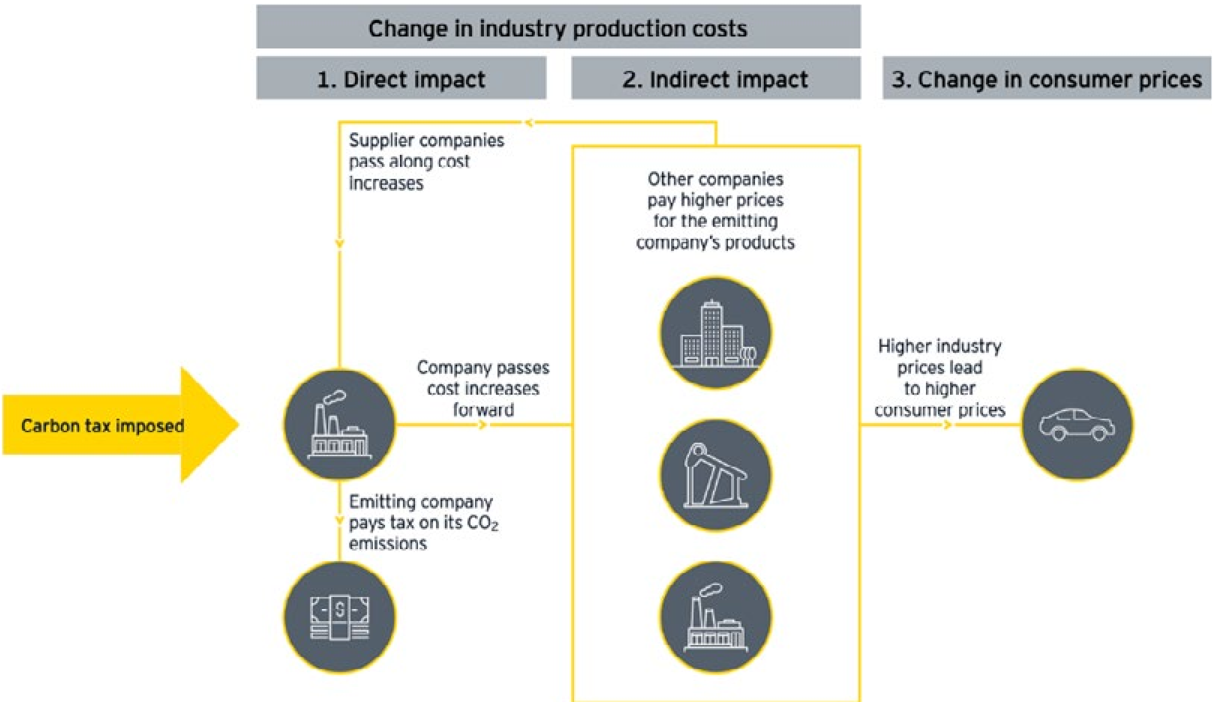
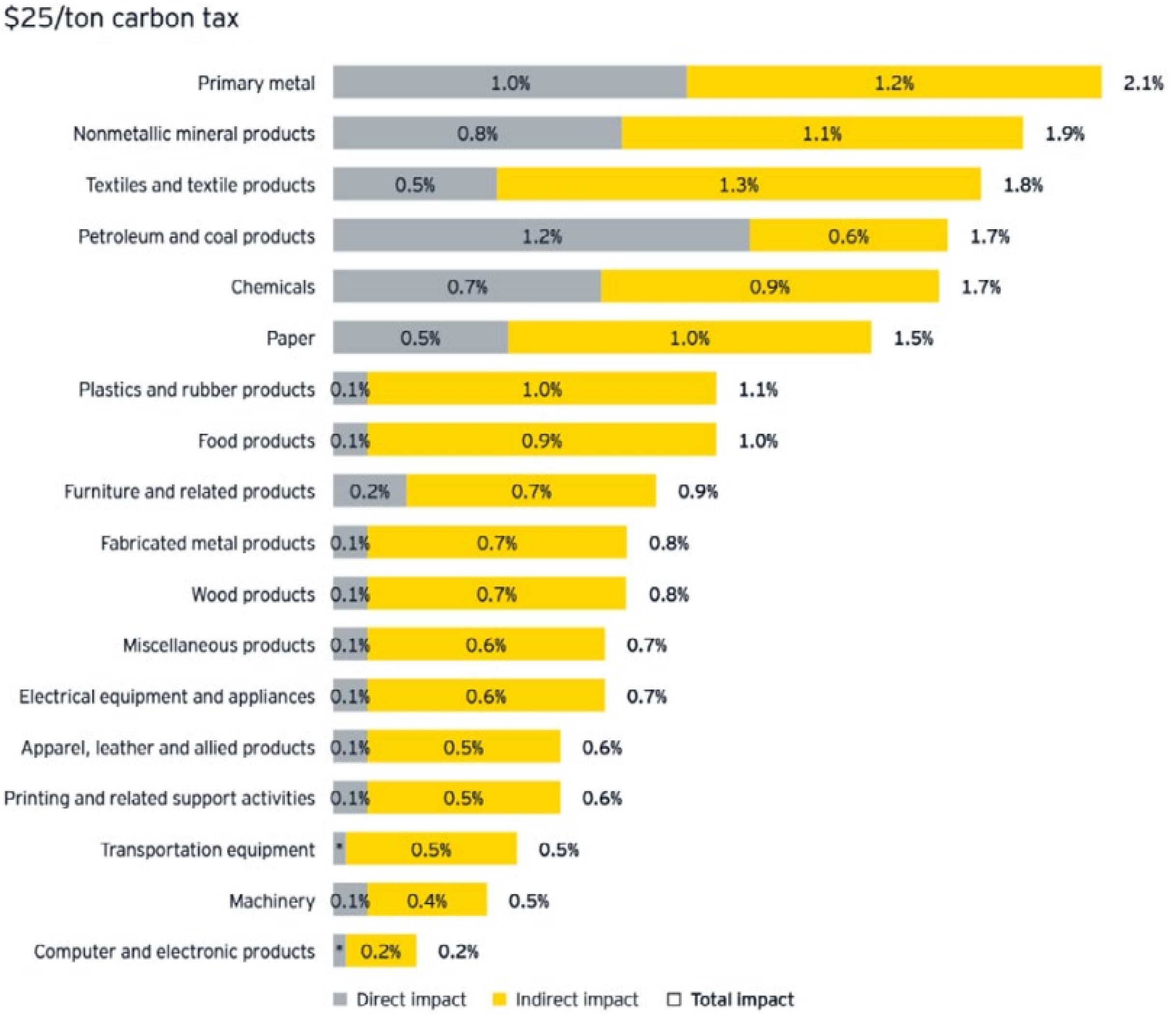


Figure 5: Estimated impact of a carbon tax on industry production costs by manufacturing subindustry (EY, 2020)



As carbon prices rise to accelerate the transition, the industrials sector will face higher costs and potentially lower profits (RFF, 2020b). An analysis of the world's 20 largest steel companies found that 14% of the companies' net present value is at risk from a carbon price rise of US$100/t$CO_2$ by 2040, under a scenario limiting global warming to 2°C, with the risk ranging between 2.5% and 30% for individual companies (CDP, 2019b). In 2019, ArcelorMittal, a multinational steel corporation, blamed high carbon prices in Europe as the reason for a decrease in its steel production (CNBC, 2019). Similarly, in 2021, at a carbon price of EUR55/tCO_2, the European Cement Association stated that the EU cement industry's CO_2 costs accounted for 8–10% of total production costs. The Association claimed that at an EU ETS price of 90 Euros, the share of CO_2 costs of total cement production costs would rise to 12–15% (European Cement Association, 2021).

As businesses face rising production costs due to the implementation of carbon prices, businesses could pass on these increased costs to consumers. As a result, consumers could be affected by higher final prices for carbon-intensive industrial products (IEA, 2020b). A study by Stede *et al.* (2021) found that a carbon price of US$31/t$CO_2$ (EUR30/ tCO_2) could cause up to an increase of 50% in product prices in the industrials sub-sectors (Figure 6). Cement was found to be the most vulnerable to the carbon price, with a maximum price increase of about 50% for cement clinker and 28% for Portland cement. Next in line were steel, iron, and aluminum, with price increases ranging from 17–25%. Plastics and pulp showed the smallest changes in product prices due to the carbon price. Some industrial firms have already begun passing down carbon prices to European customers in the form of "carbon surcharges". Last year, the German steel company ThyssenKrupp estimated that the cost of emissions was about EUR95–100/ tCO_2 and the surcharge was calculated based on the fact that the steelmaker buys around 20% of its emission allowances, thus introducing a US$24–25 (EUR23–24) per ton carbon surcharge. Similarly, steel giant Tata introduced a US$12.30 (EUR12) per ton surcharge. Market participants anticipate the implementation of surcharges will become more widespread and that such surcharges will increase in price as carbon costs rise (Argus, 2021).

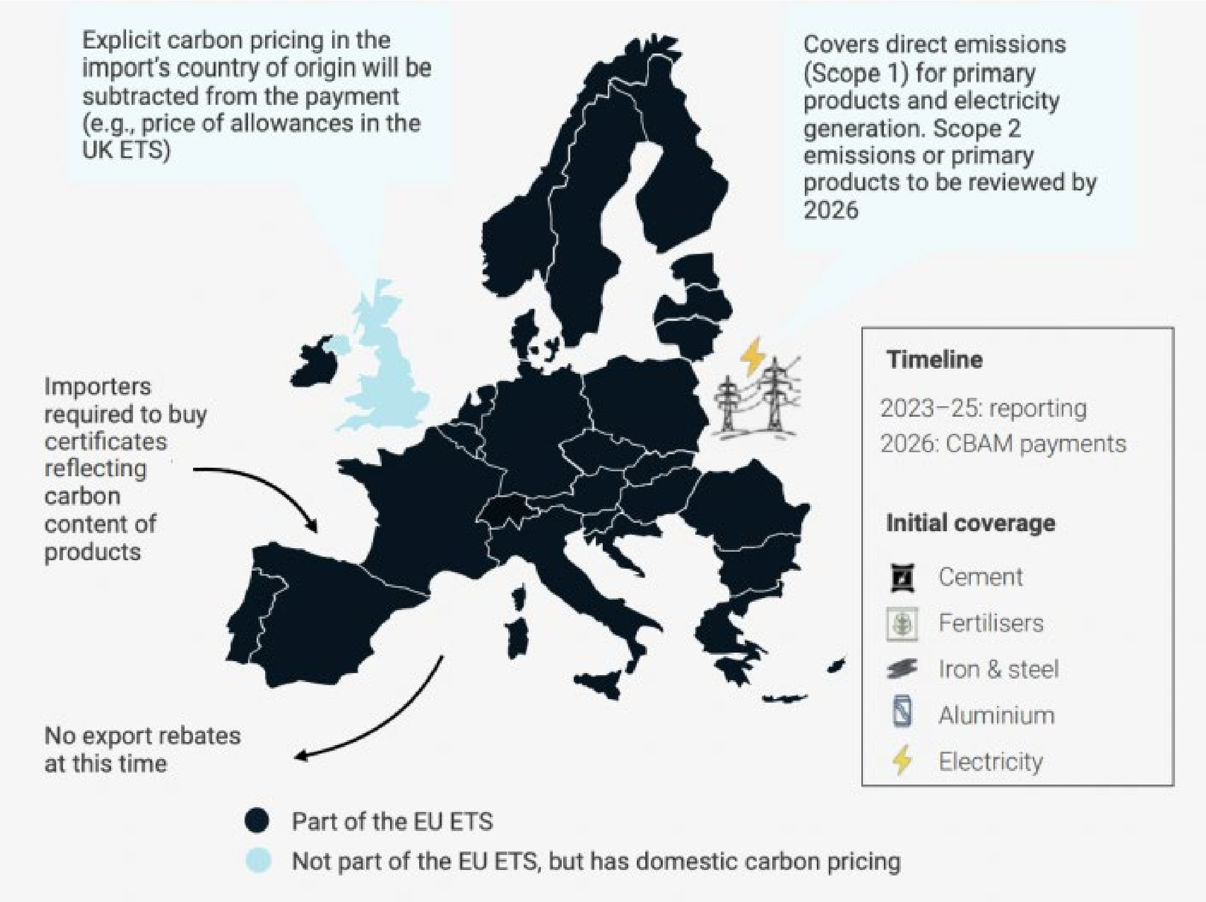
Figure 6: Maximum percentage price change from a carbon price of 30 EUR/tCO_2 for industrial sub-sectors (Stede *et al.*, 2021)

ProdCom/ NACEv2.2 code	ProdCom/ NACEv2.2 name	Price change [%]	Material
23511100	Cement clinker	49.3	Cement
23511210	Portland cement	28.2	Cement
24101100	Pig iron and spiegeleisen in primary forms	25.8	Steel
24102110	Flat semi-finished products (of non-alloy steel)	21.2	Steel
24421130	Unwrought non-alloy aluminium	17.6	Aluminium
20162090	Polymers of styrene, in primary forms	4.0	Plastics
20163010	Polyvinyl chloride in primary forms	6.4	Plastics
20165230	Polymers of vinyl acetate, in primary forms	3.8	Plastics
20161050	Polyethylene in primary forms	3.3	Plastics
17111400	Mechanical wood pulp	0.7	Pulp
17111200	Chemical wood pulp, soda or sulphate	0.5	Pulp

Increased production costs from carbon taxes could also affect the competitiveness of industrial companies. However, the extent to which this will happen varies according to the carbon price implemented from country to country. In countries with high carbon prices, industrial companies will have an economic disadvantage to companies situated in regions with no or low carbon prices. For example, the European Cement Association has blamed the European carbon price for an increase in cement imports by 25% in 2020 (European Cement Association, 2021). Furthermore, the implementation of carbon prices globally can potentially lead to emissions "leakage", where industrial companies may reduce production costs by shifting operations to countries without a carbon price (RFF, 2020b). A study by Boutabba and Lardic analysed the risk of carbon leakage under the EU ETS (Boutabba and Lardic, 2017). The results revealed the steel sector is sensitive this "leakage."

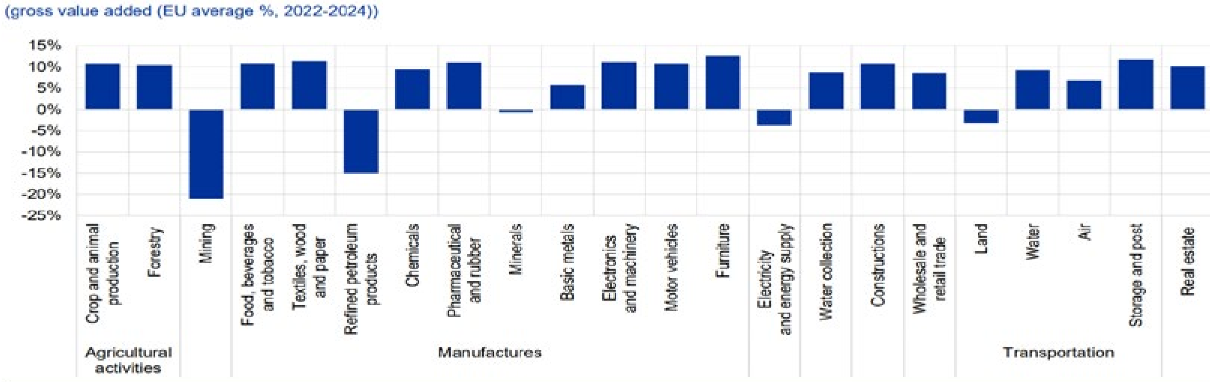
The EU's Carbon Border Adjustment Mechanism (CBAM) has been developed to address the potential risk of emissions leakage as it regulates the carbon intensity of imported iron, steel, cement, and aluminum (Figure 7). EU CBAM aims to level the playing field for domestic and imported products. Under CBAM, EU importers will need to purchase carbon certificates corresponding to the carbon price for the item produced in the EU's carbon pricing scheme. If the importer can show they have already paid a carbon price to another company, then the cost will be deducted from the producer. CBAM on iron, steel, cement, and aluminum will be phased in gradually. A reporting system will be implemented in 2023 and importers will begin paying in 2026. Canada and Japan are also considering similar CBAM initiatives (European Commission, 2021).

Figure 7: Implementation of carbon border pricing for the EU CBAM, focusing first on cement, fertilizer, iron and steel, aluminum, and electricity (UNEP FI, 2022)



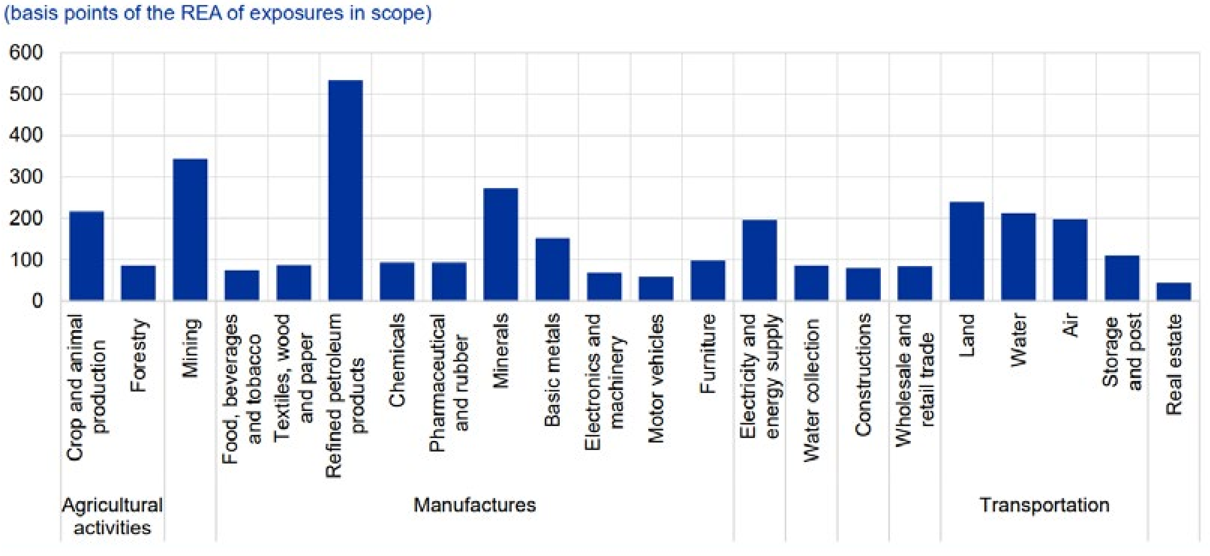
Results of a supervisory climate stress test by the European Central Bank (ECB) showed the impact for financial institutions of an increase in carbon price from 2022 to 2024 on carbon-emitting sectors, including the industrials sector. The test adopted a short-term disorderly transition risk scenario. The exercise found that shocks from a rapid increase could lead to a reallocation of resources in the economy. This reallocation could be substantial in sectors that are strongly dependent on fossil fuels, such as industrials. For example, the test demonstrated that the gross value added for the refined petroleum products sub-sector would shrink by about 15% from 2022 to 2024 (Figure 8). Similarly, the refined petroleum products sub-sector would experience aggregate loan losses of more than 500 basis points for banks, while the cumulative loan losses for the chemicals sub-sector would amount to around 100 basis points for banks (Figure 9) (ECB, 2022).

Figure 8: Sectoral impact of ECB's short-term disorderly scenario ([ECB, 2022](#))



Sources: NGFS and ECB calculations.

Figure 9: Cumulative loan losses in the ECB's short-term disorderly transition scenario ([ECB, 2022](#))



Sources: Bank submissions and ECB calculations.
Note: REA stands for risk exposure amount.

Case study 1: Carbon pricing risk

Chevron Phillips Chemical—2022 Climate Risk Report

Climate-related policy risks

Changes in the regulatory environment, including those driven by climate related issues, could affect our operations. For example, legislation, regulation and other government actions related to greenhouse gas emissions and climate change could increase CPChem's operational costs and impact demand for CPChem's products. We attribute our climate policy and regulatory risk to three priority topics: upstream regulation of oil and gas, carbon pricing mechanism and increased regulation of end markets. Regulations that limit the geographies where oil and gas may be extracted or that increase the cost of extraction could decrease oil and gas production and impact CPChem's margins on downstream products, such as polyethylene. Similarly, carbon pricing mechanisms, such as carbon taxes, or cap and trade systems, could increase CPChem's costs of direct emissions and the cost of foodstocks or other materials where carbon prices are passed through by suppliers. Additionally, regulations on downstream uses of CPChem's products, such as plastic or bottle taxes, or single use plastic bans could decrease demand for CPChem's products.

Mitigating actions

To address the risk of carbon pricing and to plan for a potential lower carbon future, we plan to take steps to mitigate exposure. The most impactful action is reducing our carbon intensity- now and in the future. CPChem's focus on advantaged feedstocks, such as ethane, has positioned our ethylene assets to produce ethylene at a lower carbon intensity than naphtha cracking assets. Further, our focus on energy efficiency, sourcing of electricity and steam from cogeneration assets, as well as reduced reliance on coal for energy needs, has strategically positioned or assets to succeed in a low carbon environment in the short-term.

2. Public policy restrictions

Other transition-focused regulatory restrictions will affect the operations of industrial sector companies. Such restrictions can come from bans, stringent processes, improved standards, and increased environmental violations. For example, the EU has introduced updated environmental frameworks for the industrials sector. These include introducing more stringent permitting processes for new and existing facilities, incentivising energy efficiency and innovation, and setting stricter pollution limits (European Commission, 2022). The International Energy Agency (IEA) has also highlighted the benefits of taxing unsustainable petrochemical disposal techniques (IEA, 2018c). Policies regulating the carbon intensity of imported products will affect the market for industrial products globally.

Various governments are also implementing restrictions on industrial products that can negatively impact the sector. For example, in a policy document released in 2022, China announced plans to ban new steel and cement projects in sensitive zones. The move forms part of the government's plans to establish a zoning system to reduce heavy industry in polluted regions, river basins, and urban areas (Reuters, 2022b). A ban on fertilizer, meanwhile, can affect ammonia producers as ammonia is an important base material for synthetic fertilizers due to its high nitrogen concentration. In 2021, Sri Lanka temporarily banned synthetic fertilizers to reduce imports and promote local, sustainable, organic farming (Vox, 2022). Similarly, the environmental campaign group Greenpeace called on the Government of New Zealand to implement a phased reduction of synthetic nitrogen fertilizer and a complete ban on its sale, production, and importation by 2024. The Environment Select Committee of the country's Parliament announced that a decision on the matter would take place in 2023 (Feds News, 2022).

A large number of countries have also banned the use of single-use plastics. The list includes Kenya, Thailand, France, and Rwanda, among others. Rwanda, for example, enacted a law in 2019 prohibiting the manufacture, importation, use, and sale of single-use plastic items, tightening a 2008 ban prohibiting the importation and use of polythene bags. Under the law, people who manufacture, import or sell polythene bags and single-use plastic items are liable to the dispossession of the items and a fine of between 300,000 and 10 million Rwandan francs (US$330–11000) (Xinhua, 2020). Rwandan manufacturing companies have complained that the government has not provided enough subsidies and support to transition to producing alternatives. In July 2022, meanwhile, India implemented a temporary ban on polystyrene products such as plastic straws used for low-value packs of beverages. The measure increased costs from 0.25 rupees to 1.25 rupees (US$0.003 to 0.015) per unit as companies switched to imported paper straws (Economic Times, 2022). During the ban, the Puducherry Pollution Control Committee issued a closure order against two manufacturing companies—Devi Industry and Sangunathan Polymers—for manufacturing banned single-use plastic items (The Hindu, 2022).

At COP26 in 2021, 197 countries agreed to accelerate efforts to phase out inefficient fossil fuel subsidies (IMF, 2022b). Pressure to remove government subsidies on fossil fuels in order to reduce emissions could significantly increase energy costs for industrial businesses due to their high reliance on such fuels. The Government of Nigeria provides an illustrative example. In 2022, it announced the removal of the country's oil subsidy. At the time, the price of petrol was at 170 naira (US$0.38) per litre, but estimates by the Nigerian Government's Department of Petroleum Resources (DPR) suggest prices in 2023 could increase nearly fivefold to around 1,000 naira (US$2.26) per litre due to the subsidy removal (Legit, 2022). Officials have warned that the high fossil-consuming industrials sector will be at the most risk of decreased profits, increased competition from international companies, and transitions to lower fossil-intensive practices in the global industrials market (Legit, 2022).

Increasingly, the petrochemical operations of several major oil companies have been specifically targeted by regulators for environmental violations. Common examples include improper waste disposal, releasing GHGs in amounts beyond their regulatory caps, and falsifying lab data pertaining to environmental regulations (Cornell Law School, n.d.). In a notable case, the oil companies Chevron and Phillips 66 agreed in March 2022 to a US$118-million upgrade to petrochemical plants based in the United States. The move followed a settlement with the US Department of Justice for failing to comply with the Clean Air Act (Reuters, 2022a). Similarly, US regulators also ordered the large chemicals manufacturer Dow to spend US$294 million to reduce air pollution in Texas and Louisiana in 2021 (Reuters, 2021a).

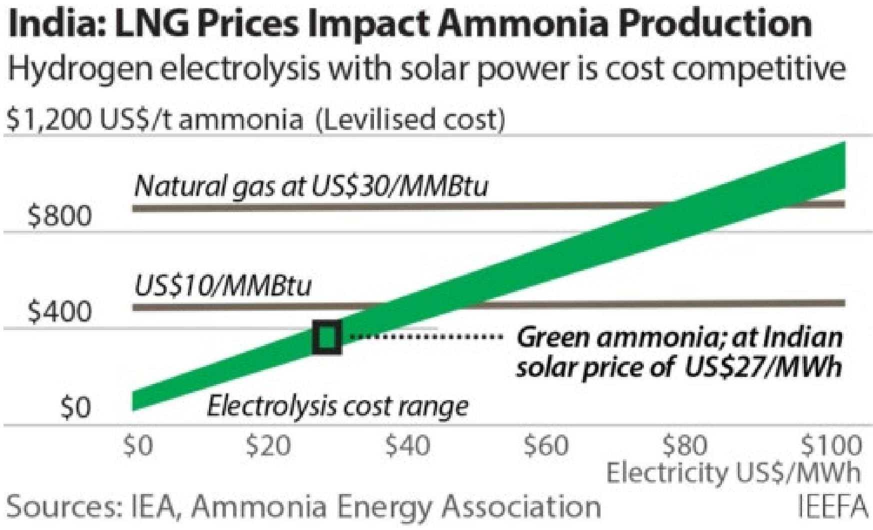
3. Technological shift and advancement of low-carbon technologies

As mitigation efforts grow to decarbonise carbon-intensive processes, technological advances such as switching to lower-carbon fuels, increasing recycling, and innovating new production techniques can help the industrials sector reduce its carbon footprint (OECD, 2018). However, as less carbon-intensive alternatives develop and occupy a greater share of the market for industrials, this will pose risks for incumbent, high-emissions producers.

'Green' ammonia

Unlike conventional ammonia, produced by the fossil intensive Haber-Bosch process, low-carbon ammonia—known as "green" ammonia—is produced using renewable energy and is carbon-free (Royal Society, 2020). Demand for green ammonia as a responsible fuel is expected to grow substantially. Green ammonia plants have been installed in many countries, including Japan, Australia, the United Kingdom, and the United States, to generate hydrogen and energy for chemical reactions (MAM, 2022). The global green ammonia market is expected to reach US$5.5 billion by 2030 and is projected to grow at a compound annual growth rate of 75% from 2022 to 2030 (Precedence, 2022). By 2032, the share of green ammonia is estimated to be about 4% of the global ammonia market (FMI, 2022). Massive fertilizer costs and the desire for increased energy self-reliance could become key drivers for countries to shift to green ammonia from conventional ammonia. For example, the Government of India budgeted a fertilizer subsidy of US$14.2 billion for 2022–2023. However, due to high and volatile gas prices driven by Russia's invasion of Ukraine, traditional fertilizer prices have reached record highs (Figure 10). High gas prices are adding pressure to increase fertilizer subsidies substantially. Therefore, a shift to green ammonia could help reduce the Indian Government's spending on fertilizer subsidies (IEEFA, 2022).

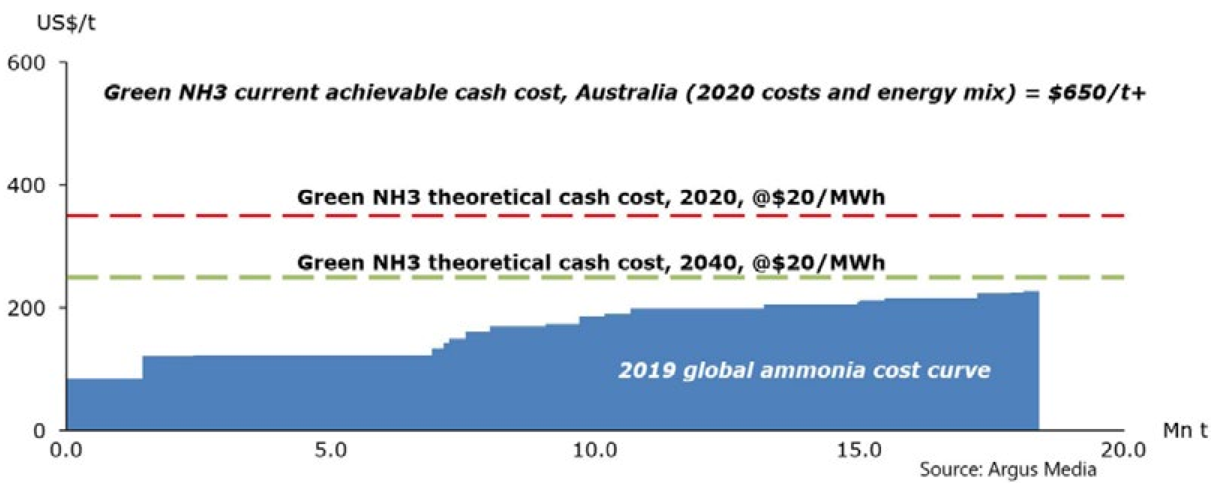
Figure 10: Impact of LNG prices on ammonia production (IEEFA, 2022)



As the market share for green ammonia rises, traditional ammonia producers face a growing risk of a shift in investments to low-carbon ammonia alternatives. For example, the Government of Egypt has recognised green ammonia as part of its economic development strategy. It has passed a decree to allow green ammonia projects to benefit from the Government's support as part of Egypt's Investment Law, which includes tax incentives (Baker McKenzie, 2022).

The biggest obstacle in the commercial adoption of green ammonia is its high production cost when compared to conventional ammonia. Figure 11 illustrates the cost gap between green and traditional ammonia. However, as governments implement carbon taxes and credits, incentives may grow for producers to shift from conventional ammonia to green ammonia. The latter could achieve competitive parity should carbon prices exceed US$50/t$CO_2$ (Argus, 2020). In 2021, global companies from different sectors joined together to launch the Green Hydrogen Catapult initiative with the goal of increasing green hydrogen production by 50 times by 2026. This would halve the current cost of green hydrogen (and, by extension, green ammonia), brining it down to less than US$2 per kilogramme—a potential tipping point to make green hydrogen (and green ammonia) the industrial sector's preferred energy source (WEF, 2021).

Figure 11: Global ammonia cost curve and green ammonia cost estimates (Argus, 2020)



Bioplastics

Bioplastics are viewed as an alternative to conventional plastics due to their lower carbon footprint. Biopolymers produced with conventional energy can reduce industry-wide GHG emissions by 25%. A shift to renewable energy sources could reduce emissions even further, by 50–75% (Posen *et al.*, 2017). In addition, biopolymers will increase competition for the traditional plastics industry as demand for them steadily grows, especially from the biomedical and packaging sectors. The global bioplastics and polymers market size is projected to expand from US$10.7 billion in 2021 to US$29.7 billion by 2026, representing a cumulative annual growth rate of 22.7% (Global News Wire, 2021). Government support for less carbon-intensive alternatives through regulation will also increase competition for traditional plastic producers. For example, the global biopolymers market size is expected to hit around US$35.25 billion by 2030, up from US$13.7 billion in 2021 (Precedence, 2022). Though bioplastics are currently more expensive to produce, ongoing investments by governments and the private sector will aid in reducing production costs. For example, the UK Government recently invested GBP60 million in bioplastic (US$71.4 million), part of the biggest boost to research and development (R&D) in the country's history. A further GBP149 million (US$177 million) is expected to be invested by UK businesses by 2025 to contribute towards reaching net zero by 2050 through the development of bioplastics (BEIS, 2019).

Bio-concrete

Advancements in new types of sustainable concrete bring growing risks to the market share of traditional cement producers. One suitable alternative is bio-concrete, an innovative building material. Bio-concrete contains clay pellets, is a more durable and environmentally friendly material than conventional concrete, and can rebuild cracks through its bacterial properties that can produce limestone under specific conditions (Buildsoft, 2019). Traditional cement currently holds a market value of US$340.6 billion (FBI, 2022). In comparison, the global bio-concrete market size was valued at US$24.6 billion in 2019 but is expected to expand at a compound annual growth rate of 37% from 2020 to 2027 (GVR, 2018). In 2021, WEF and the Global Cement and Concrete Association (GCCA) launched an initiative, representing around 40% of the industry, to promote a carbon neutral concrete industry by 2050 (World Bio Market Insights, 2021). Though at present, the costs of bio-concrete remain high, the development of new methods of encapsulating the bacteria and calcium lactate in bio-concrete will reduce the cost of the product by as much as 50%, making it priced only slightly higher than traditional concrete (GK, 2022). Due to its longevity and regenerative properties, bio-concrete also can reduce costs on annual maintenance fees compared to traditional concrete. With decreasing costs and numerous benefits, bio-concrete will create increased competition for traditional cement manufacturers as carbon-intensive economies transition towards the target of net zero. The concrete sub-sector could also witness a shift in investment from traditional products to sustainable cement. For example, many investors are now investing in bio-concrete startups. Biomason of Research Triangle Park is illustrateive of this trend. The North Carolina-based firm recently raised US$65 million in Series C financing to accelerate the development of its technology for growing bio-concrete with bacteria (Tech Wire, 2022).

'Green' steel

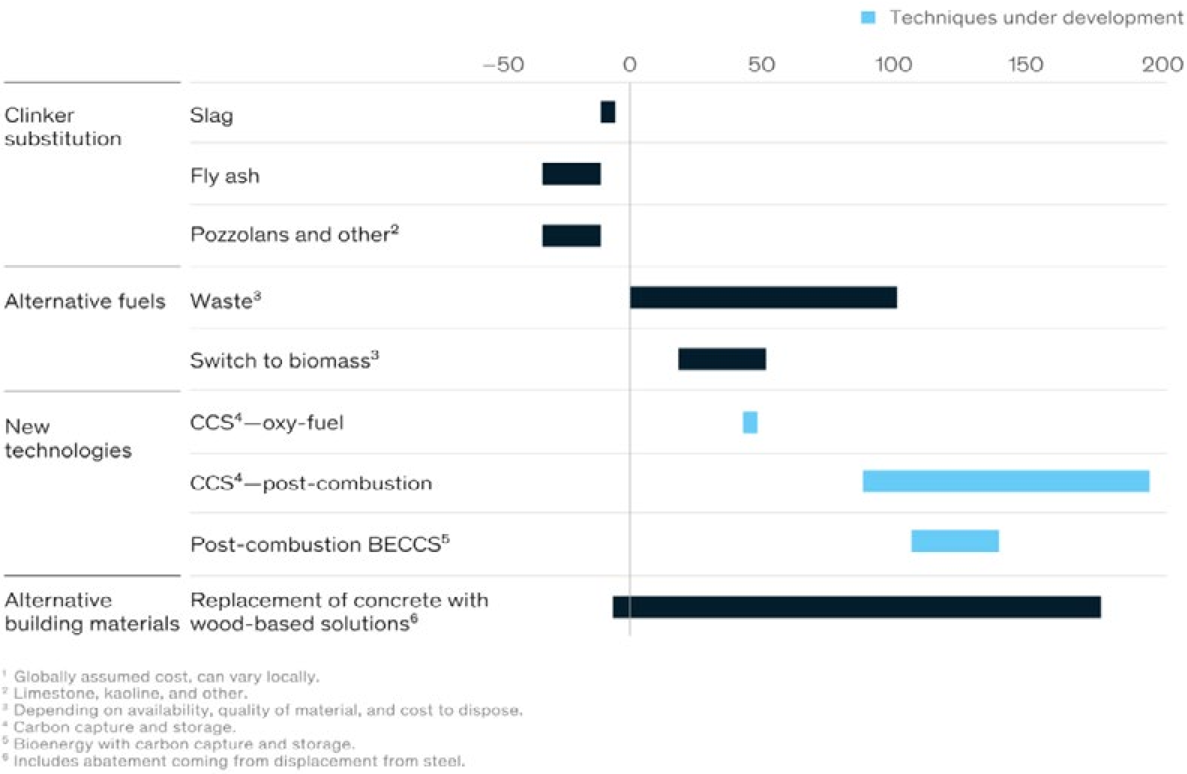
With the need to decarbonise the steel industry, 'green' steel has sparked interest for producers and investors. 'Green' steel is produced using renewable hydrogen instead of fossil coal (European Parliament, 2020). Even though replacing coal with hydrogen would currently increase the price of a ton of steel by about one-third, the cost gap between traditional and green steel could disappear by 2030 as carbon pricing rises. Decreasing costs of renewable electricity, coupled with efficiency gains from large-scale hydrogen production, could also help reduce costs (European Parliament, 2020). The global market for green hydrogen is projected to grow by 50% every year over the next decade. By 2031, the market's total value is expected to hit US$2.2 billion (EUR2.1 billion), up from US$137 billion (EUR134 billion) at present (Hydrogen Central, 2022). By 2050, green hydrogen could be the cheapest steel production method, representing 31% of the global steel market (BloombergNEF, 2021). Competition for traditional steel producers would rise substantially as a result. The shift from coal to green hydrogen for steel production on a global scale could also impact the geospatial distribution of the global steel industry. For example, access to domestic coal or easy shipping facilities for imported coal has traditionally been crucial for constructing steel mills. For green steel production, however, the tendency is more towards the local availability of cheap renewable electricity and efficient transport facilities for hydrogen (pipelines, port facilities, etc.) (European Parliament, 2020).

Private and public investments in green steel have risen in recent years, including from traditional steel producers. Back in 2022, for instance, German steel producer Salzgitter approved the largest investment into green steel of US$740 million (EUR723 million). In February 2022, meanwhile, the French Government announced its investment in green steel with an investment pledge of US$1.7 billion by 2030 to support ArcelorMittal's low-carbon programme (ArcelorMittal, 2022). The UK Government also pledged GBP250 million as part of its Clean Steel Fund in 2019, although funding has yet to be distributed (Commonwealth, 2022).

Carbon prices will play an important role in driving the transition from traditional products to less carbon-intensive alternatives. The higher the carbon price, the more attractive low-carbon technologies become. Many industrial companies are already investing significantly in embracing these technologies in anticipation of higher carbon costs. In 2021, for example, Algoma Steel announced a US$529-million (CA$703 million) plan to convert its current high-emitting blast furnace at its facility in Ottawa to a more efficient electric arc furnace. The move is expected to reduce the company's emissions by about 70%, while simultaneously increasing output by more than 50%. Algoma Steel took the measure after the Government of Canada accounced its intention to increase the carbon price from CA$40/t$CO_2$ (US$30/t$CO_2$) to CA$170/tCO_2 (US$130/t$CO_2$) by 2030. To help finance the furnace conversion, the Government provided the company with up to CA$ 420 million (US$316 million) in financial support (BNN Bloomberg, 2021).

To remain competitive with less carbon-intensive alternatives, traditional businesses in the sector will need to rely on carbon capture and storage (CCS) technology. CO_2 capture technologies can be retrofitted into existing assets of the industrials sector, such as steel and iron production plants. However, the development of CCS technology is still in its early stages and has not been massively deployed at an industrial scale. Though CCS has been applied to ethanol and fertilizer production at the commercial scale, it has not been proven yet as a viable option for traditional producers to reduce more emissions than alternatives for steel and cement. At present, there are a total of 11 industrial facilities with CCS globally. Of these facilities, 10 are chemical facilities. There is only one operational commercial steel CCS facility, located in Abu Dhabi. There are no commercial cement facilities with CCS. CCS technology in industrial applications ranges in its readiness and may remain uneconomical in the near future (IEEFA, 2022). CCS costs (Figure 12) and efficiency are also significant barriers to deploying the technology (RFF, 2020a). In summary, there are substantial risks in the reliance of the industrials sector on CCS technology given its restricted deployment to date and the numerous hurdles facing its future growth.

Figure 12: Range of abatement costs of cement decarbonisation levers (US$/$tCO_2$) (McKinsey, 2020)



Case study 2: Market and technological shift risk

HeidelbergCement Sustainability Report 2021

Market risks

One of the main market risks results from possible changing consumer preferences that may occur during the transition to a low carbon economy. Such change could lead to increased substitution of concrete with other building materials perceived as having a lower carbon footprint, such as a wood or steel. Another market risk arises from rising commodity costs which could be caused at least in part by the transition to a low carbon economy. We are also seeing an increase in electricity costs while at the same time the demand for renewable energy is on the rise. As alternative fuels and raw materials are becoming increasingly difficult to produce, owing to rising demand on the one hand and declining availability on the other, we expect a cost increase closely linked to rising CO_2 costs. Increasing costs connected with the purchase of admission allowances are anticipated for HeidelbergCement and the risk of increasing carbon leakage will disadvantage our industrial sector in the EU.

Mitigating actions

We are working to secure the necessary quantities of alternative fuels and raw materials for future production, while also exploring opportunities for a long-term supply of renewable energy generated on site at all plants, or from specific power purchase agreements with strategic partners. In addition, we use acquisitions as a strategic tool to achieve the goals of our CO_2 roadmap. The purchase of recycling company, Alex Fraser, in 2018 is one such example, as it gives us access to alternative raw materials that we need to reduce the clinker content of our concrete.

4. Emerging legal risk

Legal risk is pertinent for the industrials sector in light of its significant contributions to global emissions. In recent years, multiple environmental litigation cases have been filed against cement and steel manufacturing companies in the United States (Maplecroft, 2021). In 2016, the US Department of Justice and Indiana, Illinois, and Michigan's Department of Environmental Quality resolved the Clean Air Act litigation with the Pittsburgh-based steel manufacturer, United States Steel (USS). As part of the settlement, USS agreed to take measures to reduce pollution in its three Midwest iron and steel manufacturing plants and to commit to future environmental projects totalling US$1.9 million. The company also agreed to pay a US$2.2 million civil penalty (DoJ, 2019). In 2019, the Environmental Integrity Project (EIP), a US non-profit organisation, filed a suit alleging that USS violated federal law by failing to report thousands of pounds of hazardous emissions released from its plants (EIP, 2019). Meanwhile, a pair of cement manufacturing companies—Lehigh Cement and Lehigh White Cement—was sued by the US state of Indiana, the Environmental Protection Agency, and six other state and local governments for violating the Clean Air Act by failing to undertake technology modifications to reduce nitrogen oxide and sulphur dioxide emissions. In response, both companies agreed to pay US$1.3 million in a civil penalty and invest US$12 million in new pollution control technology (IER, 2019).

Outside the United States, 31 families in Kobe, Japan, took a Japanese steel manufacturer to court in an attempt to stop it constructing a coal-fired power plant. Should it be built, the plaintiffs in the 2017 case claimed that the power plant would emit 0.6% of Japan's CO_2 emissions from energy. Furthermore, they argued that the plant's construction would violate the right of neighbouring citizens to clean air, while also conflicting with Japan's 2030 and 2050 climate targets (Climate Case Chart, 2018). In a similar case, the Brazilian Government filed a US$3-million environmental class-action suit against steel company Siderúrgica São Luiz and its managing partner for emitting GHGs from illegally sourced coal in its operations and falsifying the certificates of origin (Grantham Research Institute, n.d.b). The case, filed in 2019, is still pending. In 2021, meanwhile, the Supreme Court of Pakistan upheld a notification by the provincial Government of Punjab that prohibited the construction of new cement plants or the expansion of existing facilities in environmentally fragile zones (Grantham Research Institute, n.d.a). Similarly, in an ongoing case in Germany, Deutsche Bank sued Total Global Steel for a breach of contract for the sale of instruments used to measure and limit GHG emissions under the EU ETS, known as Certified Emissions Reductions (CERs) (LSE, 2020; Climate Case Chart).

In 2016, Dezhou Jinghua Group, a Chinese glass products manufacturer, faced a lawsuit from the All-China Environmental Federation, an NGO under the Ministry of Environmental Protection, requesting compensation for air pollution that breached environmental regulations. The company was shown to be emitting more than a hundred tons of sulphur dioxide, nitrogen oxide, and smoke dust. The interaction of these waste gases with the human immune system exposed local residents to an increased risk of respiratory tract infections and pulmonary disease (Manisalidis et al, 2020). In 2016, the court of first hearing ordered the company to pay 20 million yuan (US$2.9 million) in compensation (China Dialogue, 2017).

5. Rise in reputational risk

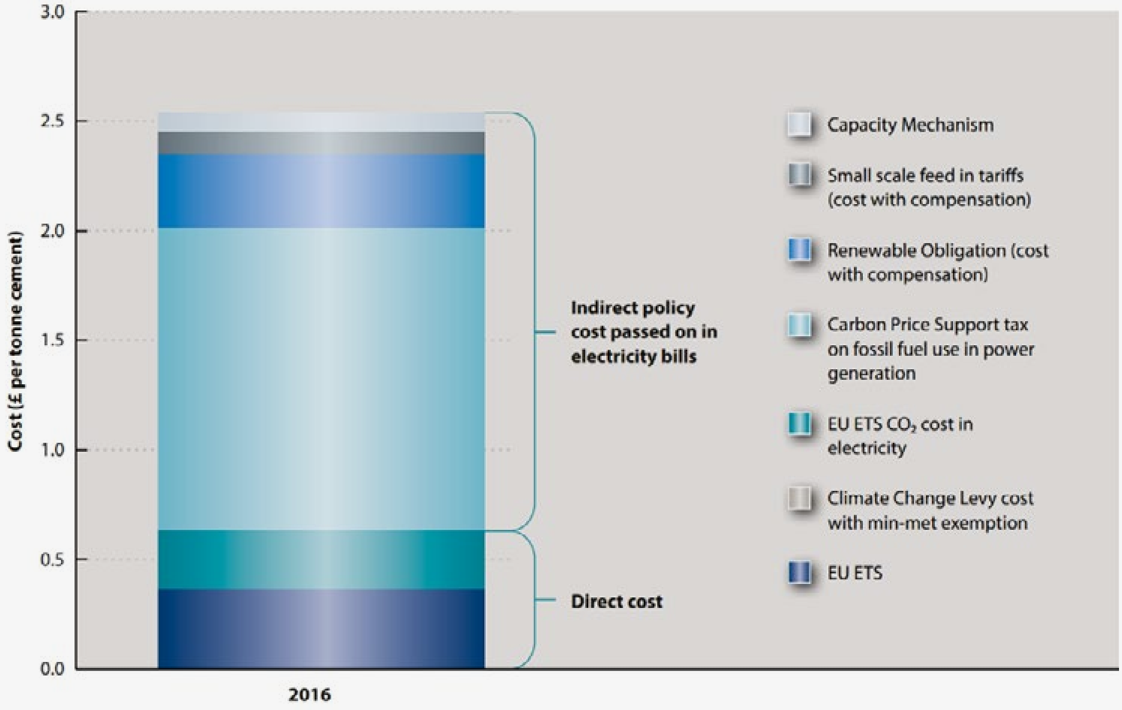
Companies taking part in industrial activities that contribute to climate change and environmental degradation face growing reputational risks. Non-profit organisations and other public-interest entities have begun running campaigns against companies linked to the climate crisis. As investor concern about the value of their investment grows and as campaigns highlighting the impact of commodities-driven activities gain attention, companies are beginning to respond to the criticisms that they face. For example, in June 2021, Extinction Rebellion targeted LafargeHolcim's cement plant in Paris to halt operations, protesting against the company's continued pursuit of growth and its high carbon emissions (Reuters, 2021b). Similarly, protestors gathered outside ArcelorMittal South Africa's *main* steel plant. The steel company is responsible for 3% of the country's emissions. Public unrest was the result of a combination of factors; a reduction in the company's annual environmental spending, its environmental non-compliance, and its lack of clarity in plans to decarbonise its operations (CER, 2022). ArcelorMittal also faced protests for its factory's environmental standards in Bosnia. As the world's largest steel maker, ArcelorMittal is a major employer in Zenica, Bosnia. However, in 2017 several thousand citizens from Zenica protested, urging the company to install filters in its steel factory in order to cut emissions. Many local residents believe that air pollution from the steel factory is responsible for higher-than-average instances of pulmonary cancer in the town (The Guardian, 2017). As the impacts of climate change grow and new environmental standards and regulations emerge, industrial companies will be increasingly susceptible to similar campaigns against high-emitting practices and will face increased reputational risks in the future.

Box A: Carbon leakage of UK Cement manufacturing

Concrete and cement manufacturing is a crucial industry for the United Kingdom. Concrete is produced at about 1,000 sites and contributes approximately GBP18 billion to the country's gross domestic product (GDP). The industry also directly employs around 74,000 people and indirectly supports a further 3.5 million jobs. However, concrete and cement account for 1.5% of the UK's total CO_2 emissions. In addition, the industry is highly vulnerable to the risk of carbon leakage due to carbon pricing implemented in the UK (CCC, 2020).

In 2017, the two most significant carbon tax contributors to the price of cement in the UK were the Carbon Price Support (CPS) (detailed below) and the Renewable Obligation (an obligation on licensed electricity suppliers in the United Kingdom to source a proportion of their electricity supply from renewable energy sources). These two policies accounted for about two-thirds of the carbon tax cement prices (Figure 13) (MPA, 2017).

Figure 13: Direct and indirect costs of climate policies per ton of cement (MPA, 2017)



In 2021, following its withdrawal from the EU in 2020, the UK replaced the EU ETS with the UK ETS. The price of UK ETS allowances (the cost per ton to emit CO_2e) has risen substantially since its inception, from GBP47/ton initially to GBP78/ton in 2022 (KPMG, 2022 via The Scottish Farmer, 2022). (DBEIS, 2019). Along with the UK ETS, the UK Government has also implemented a carbon tax known as the Carbon Price Support (CPS) (DBEIS, 2019). Due to the country's carbon pricing mechanism, the cost of carbon placed on UK cement manufacturing is higher than that of many other countries. As a consequence, UK cement imports rose from their traditional level of 10% before the introduction of CPS in 2013, to 23% in 2019. The CPS, also referred to as Carbon Price Floor (CPF), was designed to provide an incentive to invest in low-carbon power generation (UK Government, n.d.). The CPS-induced rise in cement imports highlights the fragility of domestic production and the risk of carbon leakage for the cement industry (DBEIS, 2019). Along with moving emissions produced from cement offshore, carbon leakage can also move investments, jobs, and economic benefits of cement production to other countries (MPA, 2020).

Cement and lime producers have also been excluded from the UK Government's compensation schemes. Through the Department of Business, Energy & Industrial Strategy (BEIS), for instance, some energy-intensive industries can apply for compensation for indirect costs incurred from the UK ETS and CPS. To do so, producers have to meet various criteria. However, the Government recently changed the applicability thresholds by lowering the indirect emission intensity. As a result, the UK cement industry is excluded from receiving compensation. Cement producers are therefore being affected by high energy costs—sometimes millions of pounds more than their competitors—as a direct consequence of the CPS and ETS (Mineral Products, 2022). This places them at a competitive disadvantage in international markets.

Figure 14: Emissions intensity requirements of carbon pricing compensation scheme versus average cement and lime data (MPA, 2022)

The carbon pricing compensation scheme

The original BEIS consultation set out three quantitative criteria, and an industry sector had to pas
to then be progressed to the qualitative assessment. The consultation response notes that BEIS ch
criteria and decided that a sector had to pass all three tests before progressing to the qualitative c
comparison of the change plus the average cement and lime data is shown below.

Criteria	Threshold required to be met as set out in the consultation paper	Threshold used by BEIS in determining the list	Cement average 2016-2018
Indirect Carbon Leakage Measure (ICLM)	0.22	0.36	0.41
Trade Intensity	20%	45%	12%
Indirect Emission Intensity (kgCO2/ £GVA)	1.1	0.8	3.44

Case study 3: Financial and regulatory risk

Tata Steel Integrated Report & Annual Accounts 2021–22

Climate-related risks

1. Introduction of carbon pricing in India due to climate related regulations, leading to lost in profitability.
2. Strengthening of climate risk management by the international financial community due to regulatory changes and societal pressures reducing access to capital and increasing the cost of funding.
3. Non-compliance to meeting 2°C pathway requirements, due to delay or failure in adopting low carbon technologies, impacting profitability.
4. Pace of technological development at Tata Steel not matching with pace of demand for low carbon embodied, steel products, leading to loss of market share.

Development in climate change regulation and disclosure standards reduces access to capital and increases the cost. China's continued ban on Australian coal, Indonesia's ban on coal exports in January 2022 and ongoing Russia-Ukraine conflict have already resulted in a shift in global metallurgical coal trade flows. Such political events in combination with other events such as changing weather patterns, COVID-19 related production issues, longwall moves or maintenance in various mines, increasing financialisation of commodities markets etc. have led to demand-supply gap and elevated prices of these commodities.

Mitigation opportunities

1. Increased revenue from steel recycling business (SRB) with downstream, steelmaking capacity, comprising electric arc furnaces (EAF).
2. Renewable energy capacity additions to replace thermal power based on fossil fuels.
3. Increase revenue with enhanced premium pay from sales of green certified products through environmental product declarations (EPD) an eco-labelling.

To keep ourselves ahead of the climate change risks, we intend to reduce our carbon footprint and have set out decarbonisation targets. We also continue to improve upon our disclosure of environmental, social and governance factors. We are also driving monitoring and compliance towards various emission parameters, as per the guidelines of global financial institutions. Tata Steel is focused on its path for net neutrality in Tata Steel Europe by 2050 and committed to <1.8 tCO_2/tcs for Tata Steel India by 2030. To achieve the target, Tata Steel is making a range of efforts across the organisation for GHG emission reduction activities that include increasing efficiency of operations, use of more recycling scraps, carbon capture, utilisation, storage (CCUS), and hydrogen-based steelmaking.

6. Transition risk guidance

Key transition risk questions for financial institutions to consider

1. **Gathering information**
    - Are there any new governmental standards (on energy efficiency, on fossil fuel use, on pollution/waste) that impact assets within our portfolio's footprint?
    - How rapidly is the low-carbon transition progressing across our portfolio footprint? What do energy costs, demand, and efficiency look like across our portfolio footprint?
    - What have our clients disclosed in their financial, sustainability, and climate reports regarding their transition risks?
    - Are any of our clients facing legal action related to industrial activities, pollution, or other environmental issues?
    - How many of our clients have transition plans? Do they incorporate just transition considerations into these plans?
    - Do we have emissions data for our clients?

2. **Assessing the risks**
    - Have we looked at transition scenarios to see how those risks will evolve over time? Have we considered short-term, medium-term, and long-term risks?
    - What does our exposure to higher-risk clients look like? What are the terms of our financial relationship (e.g. debt/equity, tenor)?
    - How does the emissions intensity of our clients compare to industry and regional averages?
    - What is the cost of production for our clients? How does that compare to industry and regional averages?
    - How much are clients investing in low-carbon operations and research and development?

3. **Engaging with clients and updating strategy**
    - Do our senior leaders understand the transition risks of our clients?
    - How are we helping our clients to transition to a low-carbon future? How are we supporting their efforts to advance a just transition?
    - How will the transition risks identified and assessed influence our strategy in the industrials sector?
    - What specific updates to risk management practices or business activities will be needed to appropriately consider these transition risks in our operations?

Recommendations for risk management

1. **Identify vulnerabilities in capital assets and energy use**
   - Given the capital-intensive processes of production in many industrial activities, assets are typically assumed to operate for decades. If changes in regulations, technologies, or demand cause the early closure of factories, industrials may face significant losses. Another major risk relates to the energy-intensive nature of industrial operations. For many firms, energy use and emissions footprint data can provide valuable information about transition risk. As the 2022 energy crisis has demonstrated, major volatility in energy markets can impact the value of heavy industry. With the climate transition underway, future volatility in the energy system is a distinct possibility. Governmental policies such as carbon taxes and efficiency standards can affect the bottom line of industrial operations, with the most carbon-intensive sub-sectors facing distinct headwinds. Financial institutions should explore the risks to large capital assets as well as the vulnerability of their industrials clients to energy costs.

2. **Support shift in low-carbon technologies, renewable energy usage, and efficiency measures**
   - Businesses in the industrials sector will face challenges to their current business models in the decades ahead. Many of the most farsighted firms in the sector recognise this reality and are developing (or have developed) transition plans. Many of these plans involve significant investments in renewable energy production and anticipate a shift from fossil-fuel production to diversified, low-carbon energy sources. Frequently, they also make provision for investments in lower-carbon sub-sectors, such as 'green' steel, 'green' ammonia, and bio-concrete. However, the combination of government transition policies, new competitors, and technological change may render some existing industrial firms obsolete in the future. Financial institutions can look to future-proof their investments and their financing of real assets by considering sustainability measures, such as resource efficiency, supply chain efficiency, and renewable power generation. A financial institution's industry analysts should play an active role in working with their climate risk colleagues to assess the viability of their clients' transition plans. There are a number of frameworks that exist to support this assessment, ranging from the detailed Assessing Carbon Transitions framework of the transparency specialist, CDP, through to the guidance issued by the Task Force on Climate-related Financial Disclosures (TCFD) on effective transition plans. At its heart, assessing transition plans represents an exercise in evaluating the future prospects of individual firms and sectors.

3. **Aligning to net zero**
   - Financial institutions looking to manage their transition risks in the industrials sector should engage directly with clients and support client transitions. However, while necessary, this client-level approach must complement a more strategic approach to reducing the firm's financed emissions. Over the past few years, hundreds of major financial institutions have committed to net zero by 2050 across their portfolios. Most of these institutions have joined one of

the industry-specific decarbonization alliances (e.g., Net-Zero Banking Alliance, Net-Zero Asset Owner Alliance) to support them in fulfilling their climate goals. Beyond the financial sector, net-zero alignment has also gone mainstream in government policies worldwide, with nearly 90% of global emissions now covered by a net-zero commitment. Amid growing pressures on high-carbon sectors and the decarbonization ambitions of financial and government actors, financial institutions can consider a credible and actionable net-zero commitment a way to mitigate both the systemic and idiosyncratic risks of the transition. The process of operationalizing a net-zero commitment begins by assessing baseline financed emissions. Then, institutions set targets for their portfolios and specific sectors, such as the industrials sector, using science-based scenarios. After the targets are set, financial institutions develop holistic strategies to reduce their financed emissions. These processes can be explained to stakeholders in a transparent transition plan that demonstrates not only the net-zero commitment but how the firm is mitigating its transition risks.

Adaptive and mitigating actions of clients

1. **Investing in low-carbon operating models**
   - Many activities in the industrials sector are highly carbon intensive and hard to decarbonise. However, some firms are beginning to take steps towards the adoption of lower-carbon operating models. This involves shifting to low-carbon sources of energy, investing in efficiency, and determining new processes that produce less carbon, among other measures. This process of "greening" typically requires investment in necessary capital assets as well as in systems to research and develop low-carbon energy sources. The ultimate result of this reprioritised focus should be seen in a firm's declining emissions intensity and a growing share of energy consumption from renewable sources. A firm should develop a transition plan in order to outline its journey to low-carbon operations and specify how different parts of its business will evolve during the transition.

2. **Environmental and social stewardship**
   - Strong environmental and social practices are essential across all economic sectors. However, given the historic (and ongoing) environmental issues associated with the industrials sector (from toxic air pollution endangering human health to leaks of hazardous materials devastating ecosystems), environmental and social stewardship needs to be a top priority for firms in the sector. Asset owners should promote zero-waste solutions that minimise pollution and prevent waste created from damaging neighbouring natural areas. Asset owners should also consider the potential benefits of nature-based solutions, such as wetlands that protect against flooding or tree cover that lowers heating and cooling costs for industrial operations. New construction should consider how to create factories and other assets that increase community livelihoods in concert with existing ecosystems and maximise the potential for mutual benefit.

SECTION 2:
Physical risks

Companies in the industrials sector are exposed to varying levels of physical risk from climate change depending on their geographic location and the nature of their supply chains. Increases in the frequency and severity of storms and floods can cause delays, supply chain disruptions, and chemical leaks (NGFS, 2018). Global and localised temperature increases can also lead to higher energy costs, lower productivity, and risks to employee health and safety (IEA, 2018b). Droughts are similarly problematic. As the prevalence and severity of droughts rises, so will water-intensive sectors like chemical manufacturing and paper face an increase in related impacts (Aquatech, 2019). In the same way, wildfires pose physical risks to supply chains and industrial facilities located in at-risk geographies. The most exposed industrials companies include those involved in the production of electrical products (notably semiconductors), petroleum, coal, plastics, and chemicals (Moody's, 2021). Table 4 summarises the impact of various physical risks on manufacturing sub-sectors.

Table 4: Global manufacturing sub-sectors' exposure to physical climate hazards ([Moody's, 2021](#))

			PERCENT OF ASSETS WITH AT LEAST HIGH EXPOSURE						
NAICS MANUFACTURING SUBSECTORS[3]	COMPANY COUNT	FACILITY COUNT	FLOODS	HEAT STRESS	HURRICANES & TYPHOONS	SEA LEVEL RISE	WATER STRESS	WILDFIRES
Computer and Electronic Product	290	60,183	17-22%	40-45%	11-16%	0-5%	45-50%	23-28%
Petroleum and Coal Products	41	21,433	16-21%	48-53%	10-15%	1-6%	45-50%	21-26%
Electrical Equipment, Appliance, and Component	55	17,789	18-23%	49-54%	12-17%	0-5%	44-49%	19-24%
Nonmetallic Mineral Product	69	31,858	19-24%	50-55%	7-12%	0-5%	43-48%	21-26%
Food	137	40,765	18-23%	55-60%	7-12%	05%	44-49%	17-22%
Chemical	346	92,643	18-23%	54-59%	12-17%	1-6%	45-50%	18-23%
Primary Metal	76	19,778	21-26%	45-50%	13-18%	1-6%	39-44%	18-23%
Plastics and Rubber Products	41	14,726	18-23%	54-59%	8-13%	0-5%	42-47%	17-22%
Transportation Equipment	185	75,385	18-23%	44-49%	9-14%	1-6%	42-47%	17-22%
Beverage and Tobacco Product	70	29,385	17-22%	37-42%	6-11%	0-5%	31-36%	15-20%
Machinery	147	13,906	17-22%	36-41%	10-15%	0-5%	44-49%	17-22%

Source: Moody's ESG Solutions

Case study 4: Extreme weather risk

HeidelbergCement Sustainability Report 2021

Impact of physical climate risks

One industry specific risk for HeidelbergCement is the dependence of construction activities on weather conditions. Harsh winters with extremely low temperatures or high precipitation throughout the year can have a short-term negative effect on construction activity, with direct consequences for our revenue and operating performance. The impact of extreme weather scenarios such as floods or droughts can lead to damage to our production sites, interrupt the supply to our customers, or have adverse effects on the supply of upstream products to operations. According to our analysis, heat and drought are the most important risks associated with the development of climatic conditions.

Mitigation measures

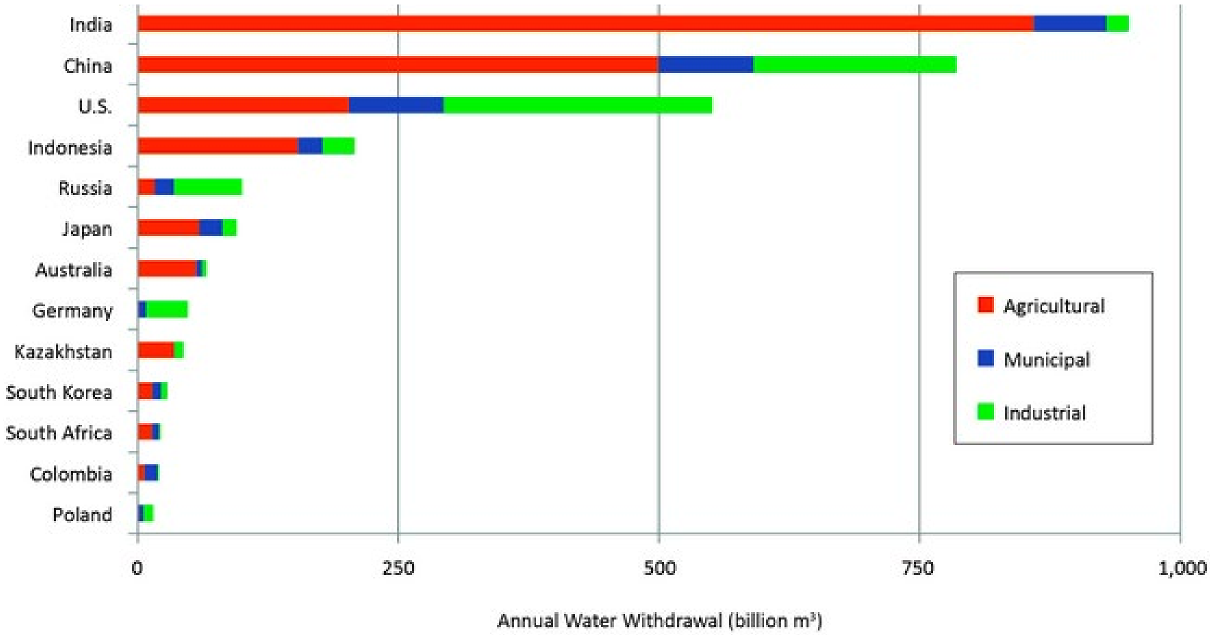
To reduce our carbon footprint we will, for instance increase the proportion of alternative fuels in the fuel mix to 45% by 2030. At the same time, we plan to further intensify the use of alternative raw materials in order to decrease the clinker ratio, i.e. the proportion of clinker and cement. By using waste materials and by-products from other industries as alternative raw materials and fuels, we also promote the circular economy. Our target is to reduce our specific CO_2 emissions per ton of cementitious material by 47% compared with the 1990 level and reach 400 kg per ton of cementitious material by 2030.

1. Droughts and water stress

As the industrials sector is highly reliant on water, the rise in frequency and intensity of drought conditions due to climate change will negatively impact water-intensive industrial manufacturing and processing. Overall, the industrials sector uses 40% of the water used by humans (Aquatech, 2019). Water usage in the industrials sector consists of indirect water used in energy production for heating, as well as direct consumption of water in industrial processes and cooling (Aquatech, 2019). Two-thirds of the industrials sector companies report exposure to water supply risks (Aquatech, 2019). Droughts can decrease the capacity for industrial production. This was seen very starkly during the drought conditions of the Rhine River in 2018, which resulted in manufacturing productivity and production falling by 1.5% across Germany and the Netherlands. Similar drought conditions in 2022 disrupted shipping along the entirety of the Rhine. This reduced industrial production as the river is used to transport millions of tons of iron ore, chemicals, raw materials, and other cargo (CIPS, 2022). Semiconductor manufacturing is one of the sub-sectors that is particularly exposed to drought risk due to its high-water intensity relative to output. In 2021, droughts forced the world's largest contract chipmaker, Taiwan Semiconductor Manufacturing, to exceed its original budget and spend over US$24 million on water trucks to maintain production levels (Forbes, 2021).

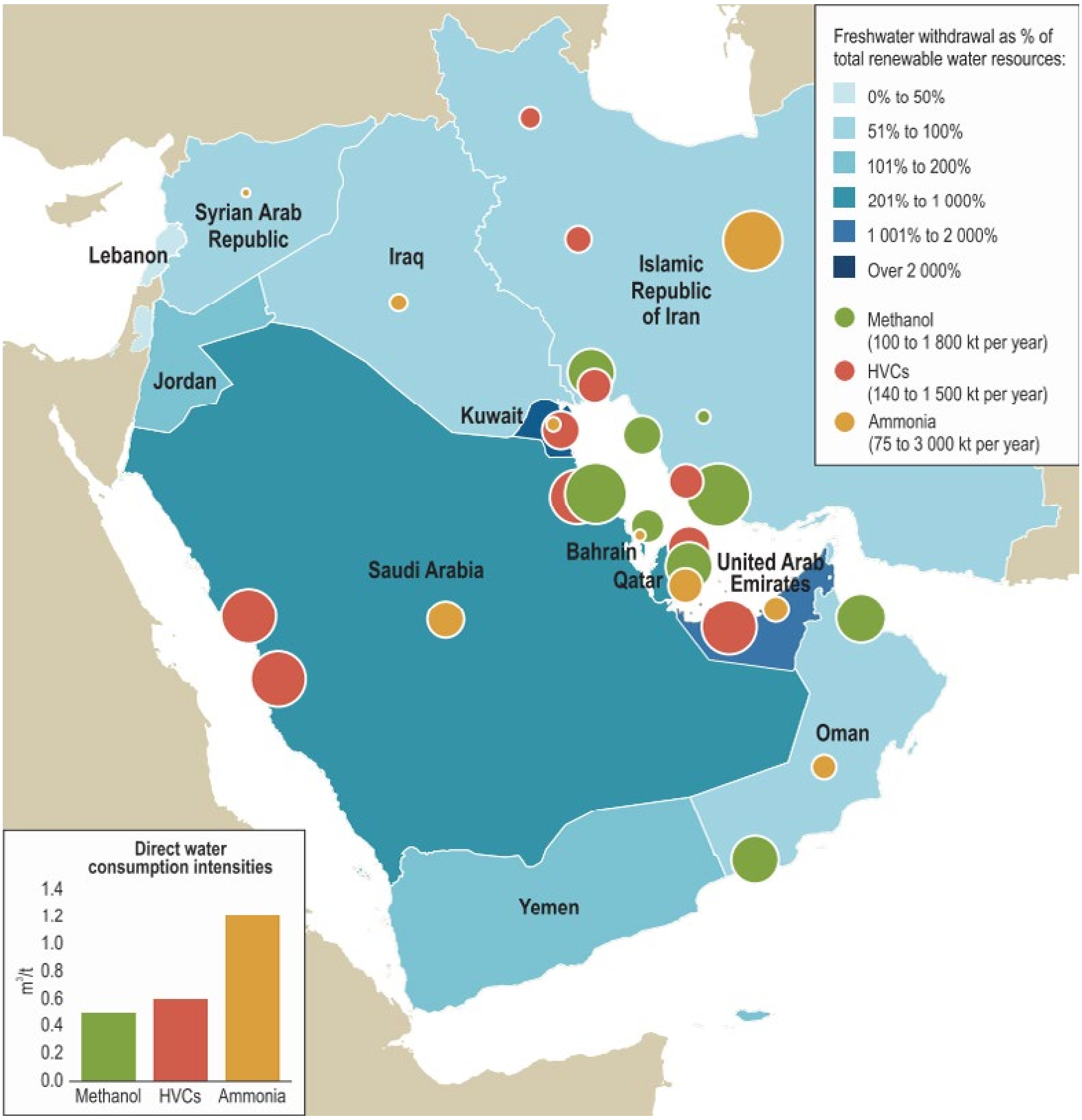
China and the United States are some of the countries where the industrials sector is the most at risk from water stress, as shown in Figure 15. In 2022, severe droughts led to hydroelectric power generation shortages in China, which affected power-intensive sectors such as aluminium smelting, steel making, cement manufacturing, and fertilizer production (DW, 2022). The droughts also caused a six-day shutdown of many factories producing processor chips in the city of Sichuan due to their reliance on energy from affected hydroelectric dams. Xuguang Electronics stated that the shutdown would reduce its output by 48,000 electronic circuits and would cause a 5 million yuan (US$600,000) decrease in its annual profit (Schiefelbein, 2022).

Figure 15: Water Withdrawal by Sector of Major Coal-producing/consuming Countries (WRI Aqueduct)



Petrochemical manufacturing facilities located in the Middle East face particular vulnerabilities given the region's long-standing problems with high water stress (IEA, 2018c). The World Bank has projected that climate-related water scarcity and the consequent impacts of droughts on key sectors, including industrials, will reduce the GDP of the Middle East by 6–14% by 2050 (Word Bank, 2016). A large proportion of chemical production in the Middle East is located along the coastline of the Persian Gulf. This area includes some of the most water-stressed countries in the world, such as Kuwait, Saudi Arabia, Qatar, and the United Arab Emirates (IEA, 2018c). Figure 16 shows the primary production hubs in the Middle East for methanol, ammonia, and high-value chemicals (the precursor of most plastics). It correlates this with the extent of water required for the manufacturing of these products and the high proportions of national water resources consumed as a consequence. An increase in chemical production in this water-stressed region will result in countries relying more on costly and energy-intensive processes for water supply (IEA, 2018c).

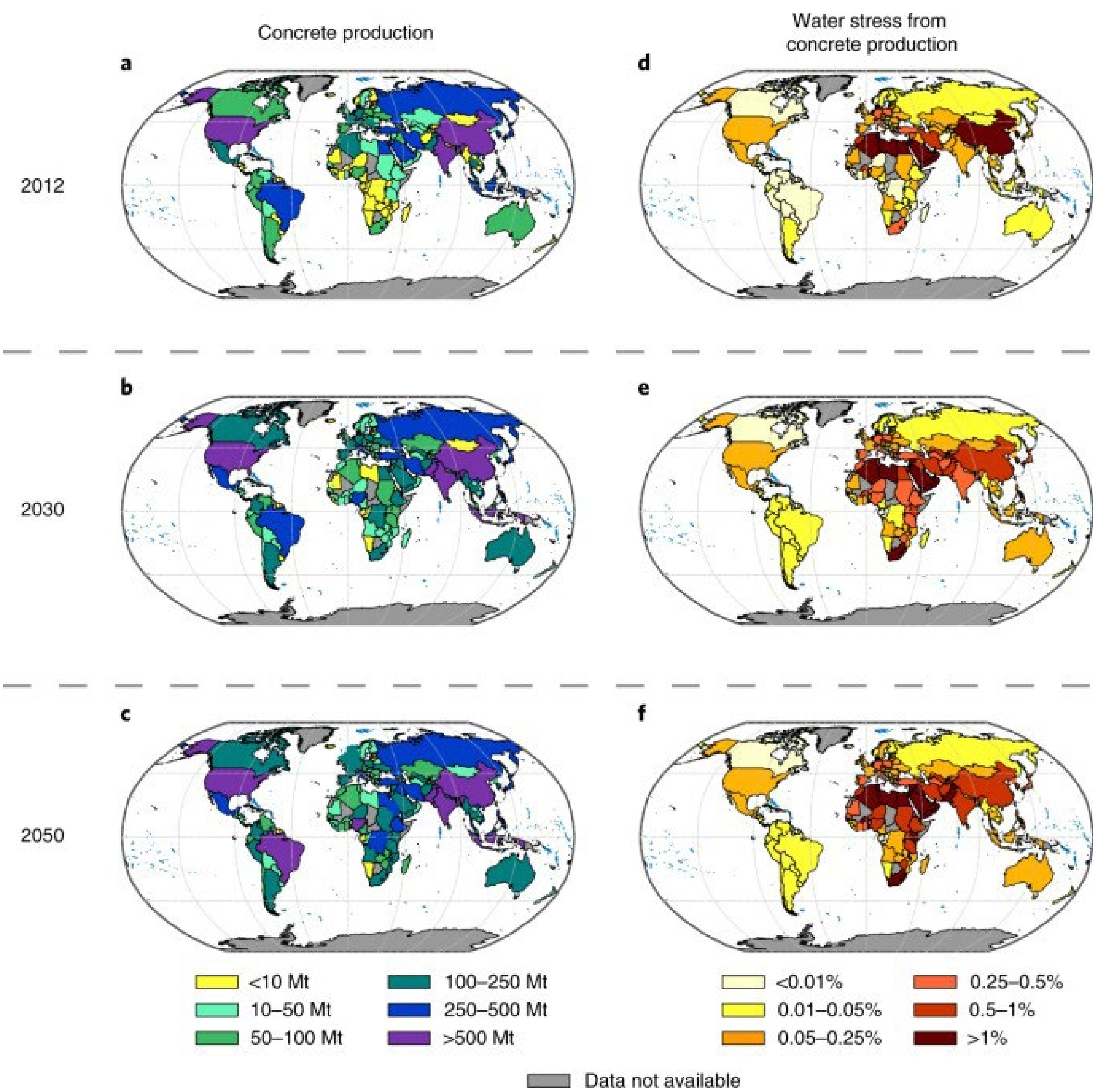
Figure 16: Primary chemical production capacity and water stress in the Middle East (IEA, 2018c)



Water is an essential resource in the steelmaking process. A total of 62,600 gallons of water is needed to produce just one ton of steel (EPA, n.d.). An assessment of the world's 20 largest steel companies found that 50% of inland steel capacity is located in regions with high water-stress risk levels. Steel companies operating in China and India are found to be the most vulnerable (CDP, 2019a). Major steel companies in India, including JSW Steel and Tata Steel, and metal producer Vedanta, flagged risks due to water shortages when the country faced an unprecedented water crisis in 2019. This led to companies investing more in water storage capacities (Economic Times, 2019). For example, JSW Steel, which operates India's second-biggest steel mill, built a new water reservoir with a storage capacity of 1.3 billion cubic feet of storage capacity at its plant in the water-scarce southern state of Karnataka to ensure adequate supply for uninterrupted operations. Tata Steel also invested in sewage treatment plants to process water for reuse and created new rainwater harvesting structures in light of the water scarcity (Economic Times, 2019).

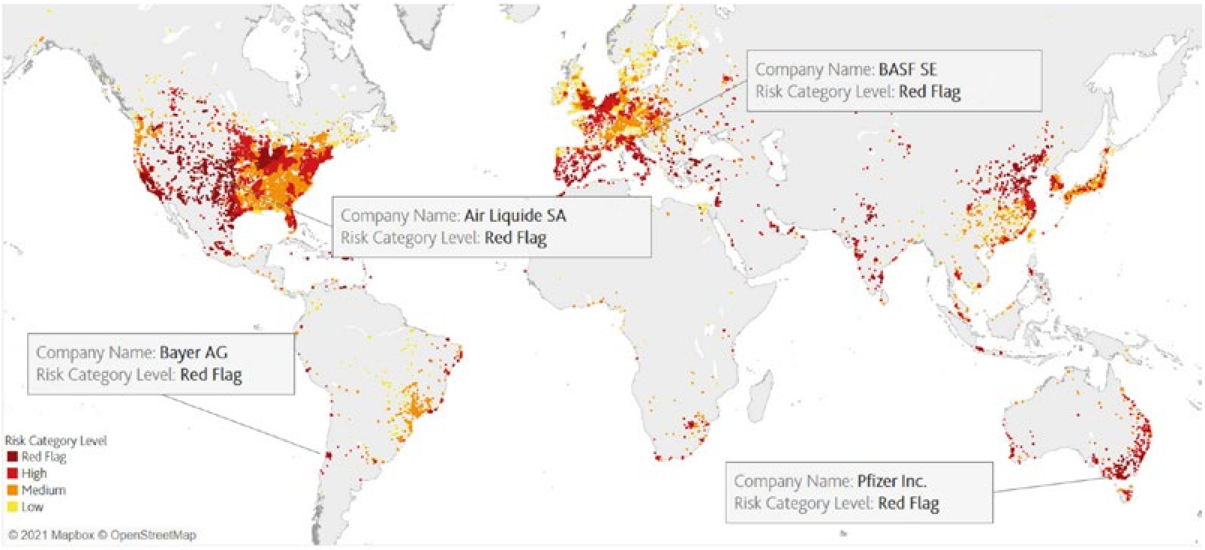
Concrete production similarly requires large amounts of water, with water usage for concrete production accounting for approximately 9% of the global annual industrial water usage. Water usage for concrete production is equivalent to the annual domestic water use of 145 million residents of the United States. Of the water usage associated with concrete production, 50% is attributable to energy use. In 2050, it is estimated that 75% of the water demand for concrete production will likely occur in regions that are expected to experience water stress (Figure 17) (Miller *et al.*, 2018). In October 2022, droughts severely impacted industries transporting goods along the Mississippi River. Construction materials comprise a notable proportion of the freight transported on the Mississippi. In 2019, for example, the quantity of cement amounted to 7.2 million tons (ENR, 2022). Low water levels in the river due to the drought caused more than 2,000 barges to back up, delaying shipments of products and increasing barge rates. The estimated supply chain impact and economic costs from the record low levels of water in the Mississippi River reached US$20 billion (Bloomberg, 2022b; WEF, 2022b).

Figure 17: Current and projected changes in water stress from concrete production relative to concrete production (Miller *et al.*, 2018)



Chemical manufacturers are also exposed to the growing risk of water stress. It is estimated that 45–50% of global assets held by this important sub-sector are exposed to water stress (Figure 18) (Moody's, 2021). In 2018, chemical giant BASF was highly impacted by droughts in Europe. The company depended on the Rhine River for cooling processes as well as the transportation of raw materials and final products. Reduction in riverine water levels due to the drought decreased chemical production, decreasing company profits by EUR 250 million. An estimated 39–44% of BASF's assets are exposed to water stress (Moody's, 2021).

Figure 18: Global chemical manufacturing companies' exposure to water stress (Moody's, 2021)



Note: Dots represent facilities. They are colored based on their water stress risk with the darker red dots being the most exposed.

2. Temperature increase

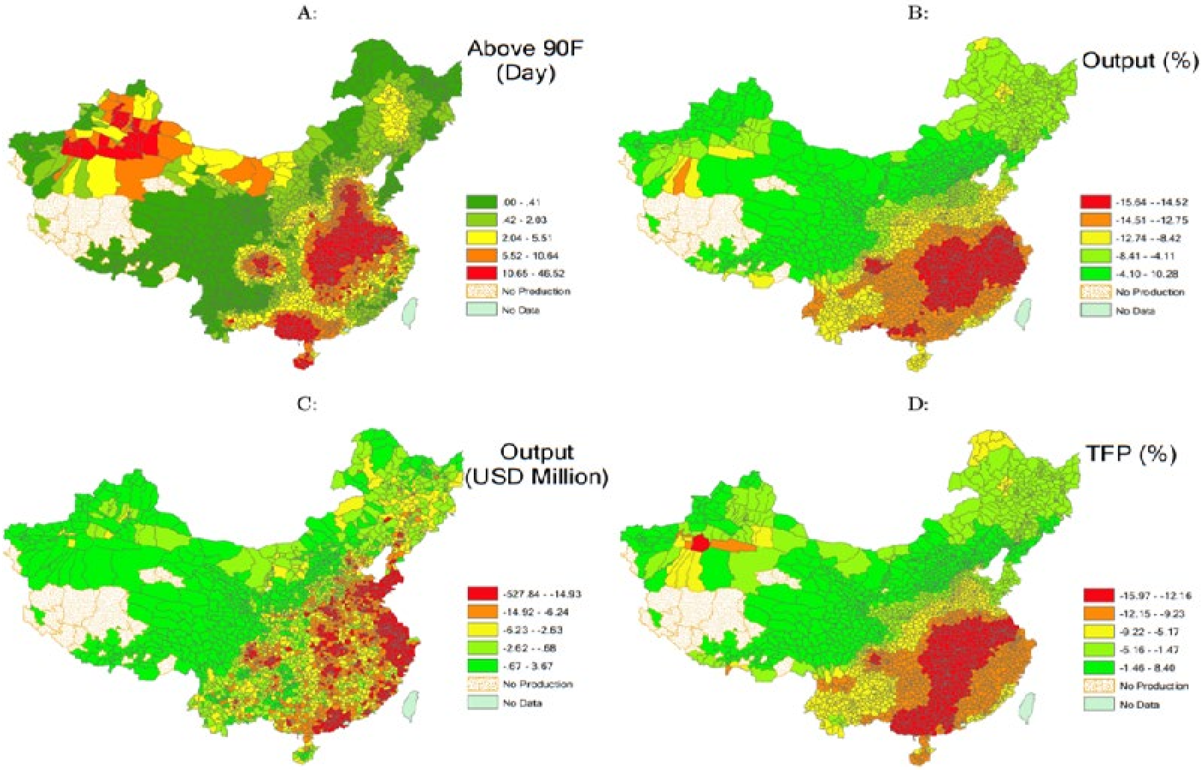
The increase in temperatures from climate change will impact the costs incurred by many producers in the industrials sector. A hotter world will require more air conditioning to maintain safe working conditions in industrial workplace settings. Unless significant energy efficiency increases are achieved, these increasing cooling needs will increase energy bills for industrial businesses.

Industrial energy use is projected to rise at an annual rate of 1.8–3.1% over the next 25 years. In developing countries and countries with economies in transition, the portion of energy supply (excluding transport) required for the industrials sector could increase by up to 50% (UNIDO). Rising global temperatures will add pressure to energy consumption due to shifting cooling and heating needs. Higher average temperatures and more regular extreme temperatures will impact productivity in industrial sector firms that require controlled temperatures for their production processes. Process cooling is common practice in industrial operations, including the cooling of machinery, cooling to prevent excess heat from chemical reactions, and the cooling of plastic and metals during manufacturing. Higher ambient temperatures will require more energy and water to cool effectively. If such cooling cannot be achieved efficiently in cases of extreme heat, operational processes will likely be hampered (IEA, 2018b).

Rising global temperatures could also negatively impact worker productivity in industrial settings, where indoor working temperatures can be higher than outdoor air temperatures (Pogacar *et al.*, 2018). Severe heat stress can hurt worker productivity. A study on approximately 70,000 manufacturing plants in India found that the output value declined by 3% for every degree above the average temperature (Somanathan *et al.*, 2021). As global temperatures rise, workers in temperate regions are also becoming increasingly vulnerable to heat stress. A study of a manufacturing plant in Slovenia, for instance, showed less-than-optimal working conditions during the summer, with an average temperature of 25°C. Of the 400 workers surveyed, 56% experienced headaches and tiredness due to the heat, and 96% deemed the temperature conditions unsuitable (Pogacar *et al.*, 2018).

Extremely high temperatures can also trigger industrial disasters affecting workers and communities through explosions, major chemical releases, fires, and chemical leakage into the air, water, and soil (UNECE, 2016; Geopolitical Monitor, 2022). For example, high temperature and drought conditions are suspected of having caused the evaporation of sulphuric acid in a reservoir at a titanium dioxide facility in Crimea. This resulted in the release of large quantities of gaseous sulphur oxide into the air, causing breathing problems and chemical burns. Over 4,000 children needed to be evacuated as a consequence (BBC, 2018). Many industrial factories around the globe are not climate controlled and instead rely on external temperatures to regulate their internal climate. High temperatures can also damage sensitive components and equipment within the industrials sector. China is one of many countries vulnerable to reduced industrial productivity due to high temperatures. In 2017, a single day temperature of above 32°C cost a manufacturing plant over US$10,000 in output ([Zhang *et al.*, 2018]). If no additional action occurs, it has been calculated that heat stress could reduce China's annual manufacturing output by an estimated 12% —equivalent to a loss of nearly US$40 billion. This could have substantial economic consequences as the manufacturing sector accounts for 32% of the country's GDP and 12% of global exports (see Figure 19) ([Zhang *et al.*, 2018]).

Figure 19: Predicted climate change impacts on temperature, output, and total factor productivity (TFP) for each county in China ([Zhang et al., 2018]).

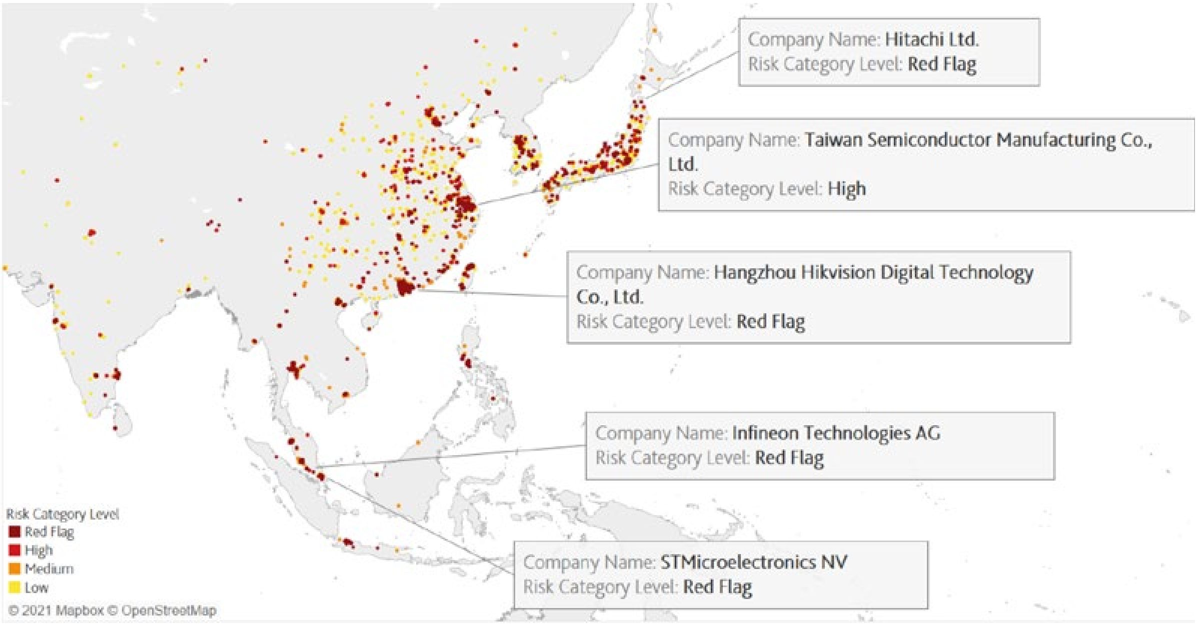


3. Intense storms and flooding

The increasing frequency and severity of storms and flooding threaten the industrials sector. Production locations can be concentrated in geographic areas where low inventory levels are held, heightening vulnerability to extreme storms and flooding. Manufacturing plants can face product defects and damage to production facilities because of stronger storms and flooding caused by climate change. A study by Moody's Analytics, for example, showed that about 19–24% of industrials-sector assets located in Asia are highly exposed to flooding. Severe flooding can cause damage to materials, expensive machinery, and products, which can lead to operations being shut down temporarily. Semiconductor manufacturing facilities are significantly exposed to the risk of flooding as they contain costly and water-sensitive equipment. If damaged, the repair costs for the equipment can substantially impact firms. For example, following the 2011 Thailand floods, ON Semiconductors permanently shut down one of its production sites due to "excessive cost required to recover and reconstruct" (Moody's, 2021).

An estimated 59–64% of companies that manufacture computers and other electronic products face a high risk of flooding in more than 30% of their facilities (Moody's, 2021). Exposure to flooding is particularly substantial for facilities in Asia, a region where many manufacturing companies operate (Figure 20). Taiwan Semiconductor Manufacturing provides an illustrative example here, with 36–41% of its facilities vulnerable to flooding (Moody's, 2021). In 2021, record floods in China's Henan province disrupted the manufacturing operations of Nissan and Apple (Business Insurance, 2021). These flooding incidents in China had a total economic cost of approximately US$25 billion (Lui *et al.*, 2021).

Figure 20: Exposure of computer and electronic manufacturing companies to flooding in East Asia in 2021 (Moody's, 2021)



Note: Dots represent facilities. They are colored based on their flood risk with the darker red dots being the most exposed.

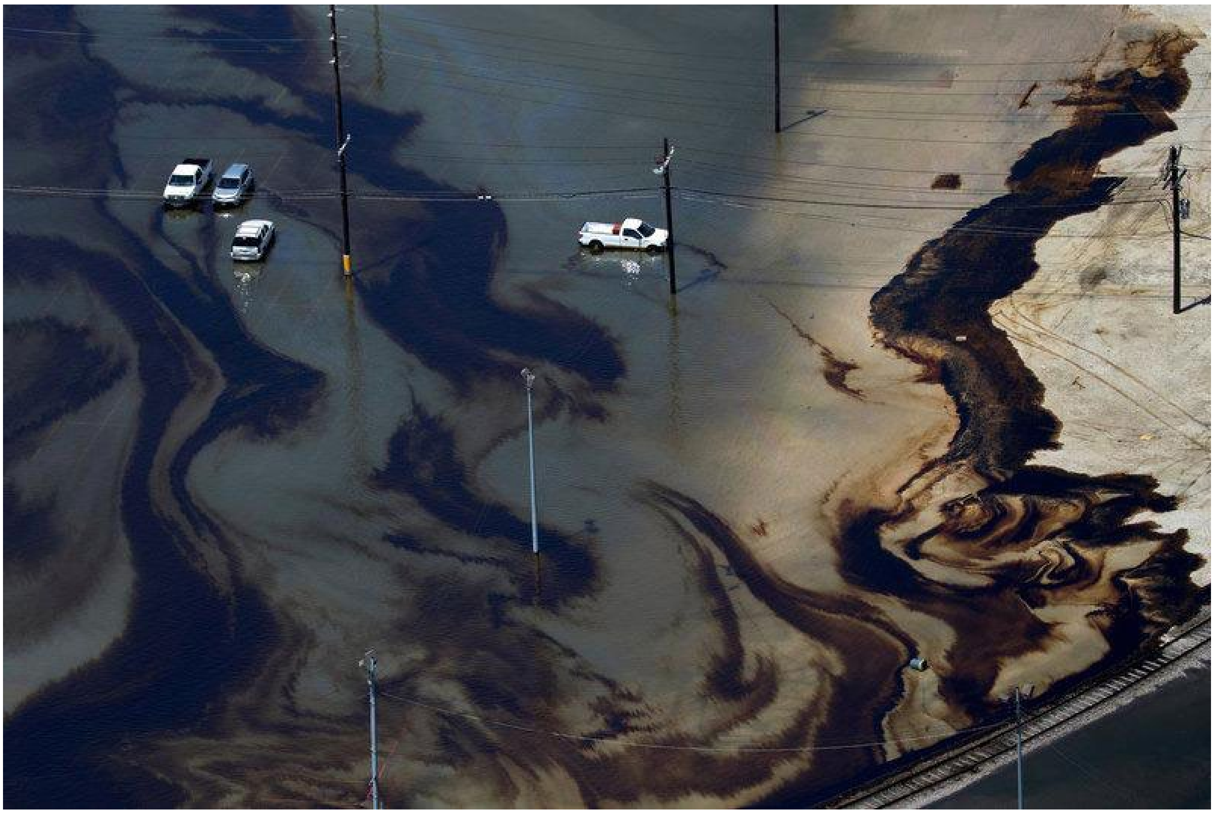
Source: Moody's ESG Solutions.

In September 2022, Typhoon Hinnamnor caused widespread flooding and power outages in South Korea. The country's biggest steelmaker, Posco, was forced to suspend operations in its plants in Pohang due to flooding in the facilities caused by the typhoon. Posco's Pohang facility accounts for 40 million tons of annual crude steel capacity for the company. The flooding caused Posco's blast furnaces to stop working (The Korea Times, 2022; Bloomberg, 2022a). In addition, a fire broke out at the facility as a direct result of an abrupt power failure caused by the typhoon (Figure 21) (The Korea Times, 2022). Posco's operating profits dropped by 71% year-on-year in the third quarter due to the halt in operations caused by the typhoon (The Korea Herald, 2022). Due to the storm, Hyundai Steel was also forced to stop operations at its plant in Pohang and increase production in other locations (Bloomberg, 2022a).

Figure 21: Fire at Posco's Pohang steel plant caused by Typhoon Hinnamnor (The Korea Times, 2022)

Globally, an estimated 18–23% of assets of chemical manufacturing companies are exposed to flooding (Moody's, 2021). Stronger storms can increase the likelihood of chemical spills or other safety incidents, particularly through damage or disruptions to power sources. Such instances can endanger employees and disrupt operations. Industrial companies often incur legal liability for these events and expose themselves to legal risk if environmental harm is not adequately managed. Chemical plants are typically located in low-lying coastal areas, which heightens risks to the chemical industry due to climate change-inflicted hurricanes, floods, and land erosion (Geopolitical Monitor, 2022). Floods and storms are responsible for a notable portion of the accidental chemical releases that occur each year (Anenberg and Kalman, 2019). A case in point is Hurricane Harvey in 2017, which cut off backup power to the Arkema chemical plant in Crosby, Texas. The plants house volatile chemicals that require constant refrigeration. The disruption to the power supply caused these chemicals to combust, spurring the evacuation of everyone within a 1.5-mile radius (Washington Post, 2017). As a result, Arkema officials faced a series of criminal indictments (Texas Tribune, 2018).

Figure 22: US Coast Guard, EPA cleaning up a dozen Texas chemical spills after Hurricane Harvey (Reuters, 2017)



Industrial supply chains, including raw materials, are especially vulnerable to climate risk (CNBC, 2021). Flooding and storms can also cause disruptions further down the supply chain, increasing costs for industrial companies. By way of illustration, extreme flooding in Europe and China in 2021 interrupted railway links and delayed the cargo movements of coal for up to 16 days. This held up international trade worth US$9 billion a day and created havoc in the shipping industry upon which the highly-globalised industrials sector is heavily reliant (CNBC, 2021). In 2021, heavy rainfall caused the Rhine River in Germany to flood, severely impeding logistics and distribution through transportation system blockages for major German steel businesses, causing delays and disruption to supply chains (S&P Global, 2021). Prices of North European Hot-Rolled Coil Steel increased by nearly EUR50 per metric ton due to the flooding event.

In 2021, meanwhile, an extreme winter storm disrupted operations at petrochemical plants in Texas, interrupting global supply chains and causing shortages of chemical raw materials. About 80% of the state's chemical production shut down. This impacted the majority of production of three key types of plastics—polyethylene, polypropylene, and polyvinyl chloride (PVC)—in the United States. A month after the storm, manufacturing operations remained disrupted, with up to 15% of capacity still non-operational. These chemical raw materials are crucial in many products, ranging from cars and medical equipment to nappies. The interrupted supply chains of key raw materials resulted in a global shortage of semiconductors. Data showed that PVC export prices increased to US$1,775 per ton, an all-time high (Financial Times, 2021).

Case study 5: Intense storms and flooding risk

Johnson & Johnson Pharmaceuticals (J&J)—CDP Climate Change 2021 Report

Increased severity and frequency of extreme weather events such as cyclones and floods

Changes to global climate, extreme weather and natural resources could affect demand for the Company's products and services, cause disruptions in manufacturing and distribution networks, alter the availability of goods and services within the supply chain and affect the overall design and integrity of products in operations. Climate change is projected to increase the intensity of precipitation events are in high latitude areas. While we are a geographically diverse company that has facilities in many countries, we have several locations in areas such as Puerto Rico with severe frequent storms. In 2017, hurricane Maria in Puerto Rico had an impact on our operations, where we have facilities that manufacture product lines across multiple segments. While J&J facilities were well prepared for this extreme weather event through our business continuity preparedness and emergency generation sources and back up water supplies, the destruction of public infrastructure resulted in business disruptions. The storm can be used as a proxy for similar risks in that equals damage to physical assets, reduce productivity on the island, availability of our product versus generics in certain markets.

Mitigation response

We approach management of physical risks or a combination of risk and climate mitigation activities. In 2015, we set a science-based goal for Scope 1 and 2 emissions to reduce emissions by 20% by 2020 and 80% by 2050. In parallel, we undertook policy initiatives, including joining the Climate Leadership Council in 2017, advocating for carbon dividend in the US, and pledging support for the C40 Cities Climate Leadership group with a commitment of US$1 million over two years. Oversight of mitigation and management of acute physical risks as an asset level lies with Enterprise Facilities Management, who manages and coordinates cross functional J&J teams and processes involved in emergency planning, response and recovery efforts for crisis events.

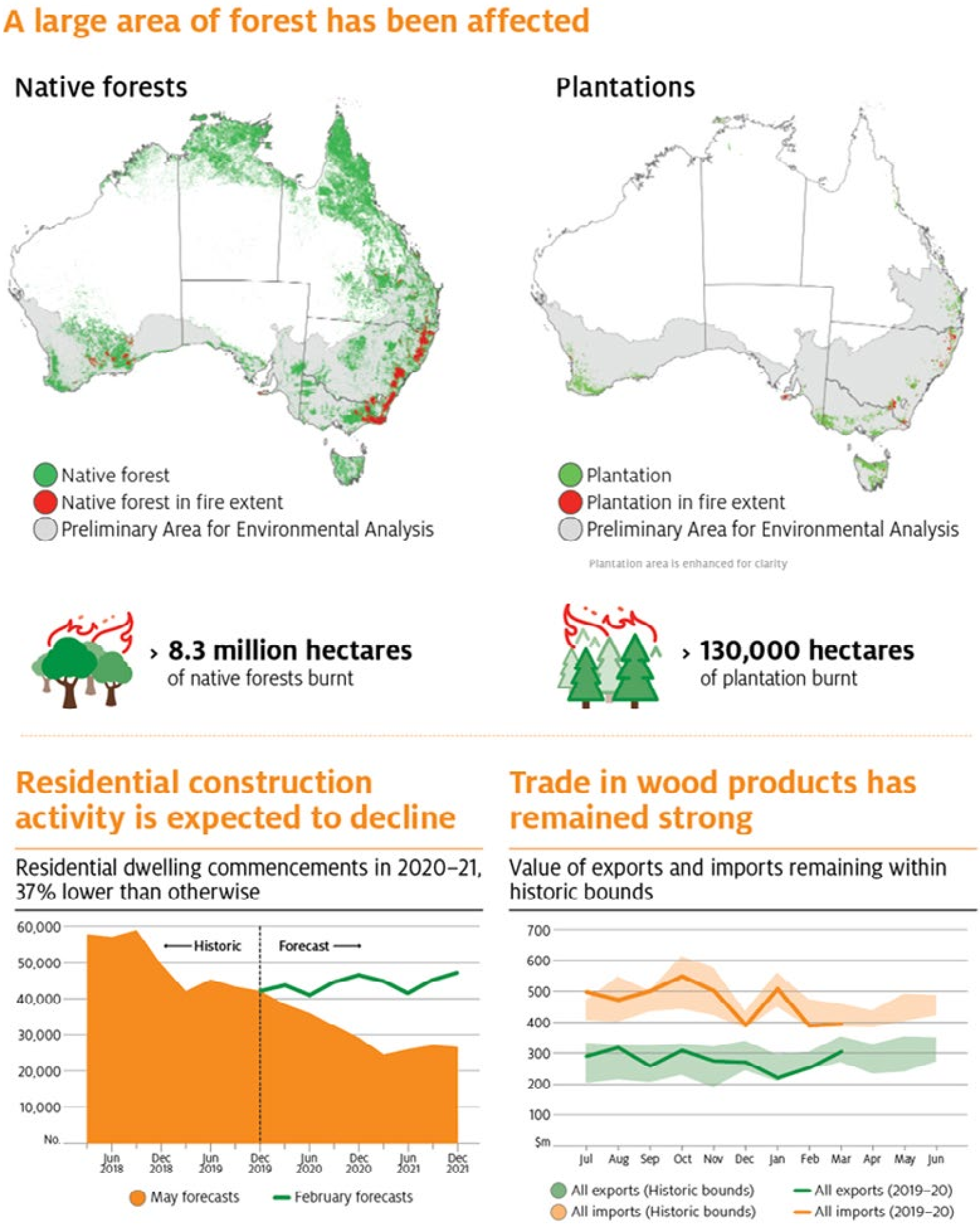
4. Wildfires

As global temperatures rise, the frequency and severity of wildfires are also expected to worsen. Industrial facilities in regions vulnerable to bushfires will encounter property damage and disruptions in operations, leading to higher costs and financial losses. Key logistics routes can also be impacted, leading to supply chain delays. This occurred during the 2021 wildfires in California, which caused disruptions to several large manufacturing facilities. Many of these facilities were located in areas at high risk of wildfires—a fact that is true for 40% of all buildings in the state (LA Times, 2022). The Californian 2021 wildfires caused approximately US$637 million in damage and US$42.7 billion in economic disruption over 80 sectors. Major manufacturing facilities were impacted and essential transit routes saw closures, leading to ruptures in supply chains and delays in manufacturing processes (Thomas, 2018). Property, equipment, and asset losses comprises some of the main direct impacts to businesses of the wildfires, while indirect impacts were chiefly felt in the region's labour markets, transportation systems, and utility infrastructure (Thomas, 2018).

The pulp and paper sub-sector is becoming increasingly vulnerable to wildfires, with potentially significant economic and social implications. In Australia, for example, the sub-sector is responsible for 12,000 direct jobs (plus over 30,000 indirect jobs) and contributes more than AU$4 billion (US$2.7 billion) to the national economy (BCP, 2020). However, the 2019–2020 Australian wildfires (which spread across more than 9 million hectares) affected up to 10% of the softwood plantations used in the pulp and paper industry (Woods, 2019).

Australia's pulp mills are expected to experience extreme shortages of softwood over the next few years due to the increase in the frequency and severity of wildfires (BCP, 2020). Figure 23 shows the hectares of plantation for industry lost to the 2019–2020 Australian wildfires.

Figure 23: Fire extent during the 2019–2020 Australian wildfire season ([Australian Government Department of Agriculture, Water and the Environment, 2020]())



Fire extent derived from the Department of Agriculture, Water and the Environment National Indicative Aggregated Fire Extent Dataset within the 'Preliminary Area for Environmental Analysis – 2019/20 Fires' current to 28 April 2020. Forest area derived from the National Forest Inventory Forests of Australia (2018) spatial dataset.

In Europe, meanwhile, wildfires in 2022 temporarily closed down manufacturing facilities across multiple countries. Italy was one of those affected. Among the main instances, a plant with 3,000 employees had to be temporarily close due to air-quality concerns ([Ansa, 2022]()). Elsewhere, up to 500 residents had to be evacuated as flames raged through their villages during the night, causing damage to property and leading some liquefied gas tanks to explode. The price tag of Italy's wildfires was estimated at around EUR10,000 for every hectare affected. This includes the costs of the firefighting operations and remediating the damaged land, in addition to the economic damage incurred (DeAndreis, 2022).

Wildfires also have the potential to impact the hydrology of the affected area in both the immediate and long term. This can, in turn, disrupt the water supply essential to the operations of many industrials sub-sectors (see 'Droughts' above). One notable risk is that ground burned by wildfires can become hydrophobic and impenetrable to water, thus heightening the probability of flooding (CWP, 2021) (see 'Flooding' above). Additionally, wildfires can pose a significant risk to the health and safety of employees due to poor air quality. Personnel may need to be evacuated from remote areas, for example. The risk of employees contracting acute and chronic health problems also exists. Potential conditions include respiratory disease, cardiovascular disease, cancer, and mental health problems, which can lead to premature mortality (Grant and Runkle, 2022). Between 2011 and 2015, municipal fire departments in the United States responded to an estimated average of 37,910 fires at industrial or manufacturing properties each year. Of these, 71% were wildfires (or unclassified). Collectively, these accounted for an estimated annual average of three civilian deaths, 38 civilian injuries, and US$265 million in direct property damage (NFPA, 2018).

Case study 6: Climate disruption risk

Tata Steel Integrated Report & Annual Accounts 2021–22

Climate related operational risks

Disruption to Tata Steel's manufacturing processes caused due to various factors such as equipment failures, natural disasters, epidemics or pandemics or extreme weather events, etc. could adversely affect operations and customer service levels. Weather disruptions or geopolitical instability puts a threat on material availability.

Mitigation measures

Tata Steel will move forward to emerge as a business leader across the hydrogen and Carbon capture and utilisation (CCU) value chain. In its effort towards decarbonisation, Tata Steel is also working towards minimising scope 2 & 3 emissions. With the advent of electrification of vehicles and renewable energy system, we are working to increase our renewable energy share along with inclusion of high range electric mobility system. As part of its sustainability initiative, Tata Steel has tied up with an Indian start-up in deploying EVs in transporting steel products. During the year under review, Tata Steel, commissioned the Carbon Capture Use (CCU) pilot plant at Jamshedpur works, the country's first steel company to adopt carbon capture technology that extracts CO_2 directly from the BF gas. Once separated, the same could be transported to different places for use in industry.

Box B: Flooding risk to manufacturing and industrial facilities in China.

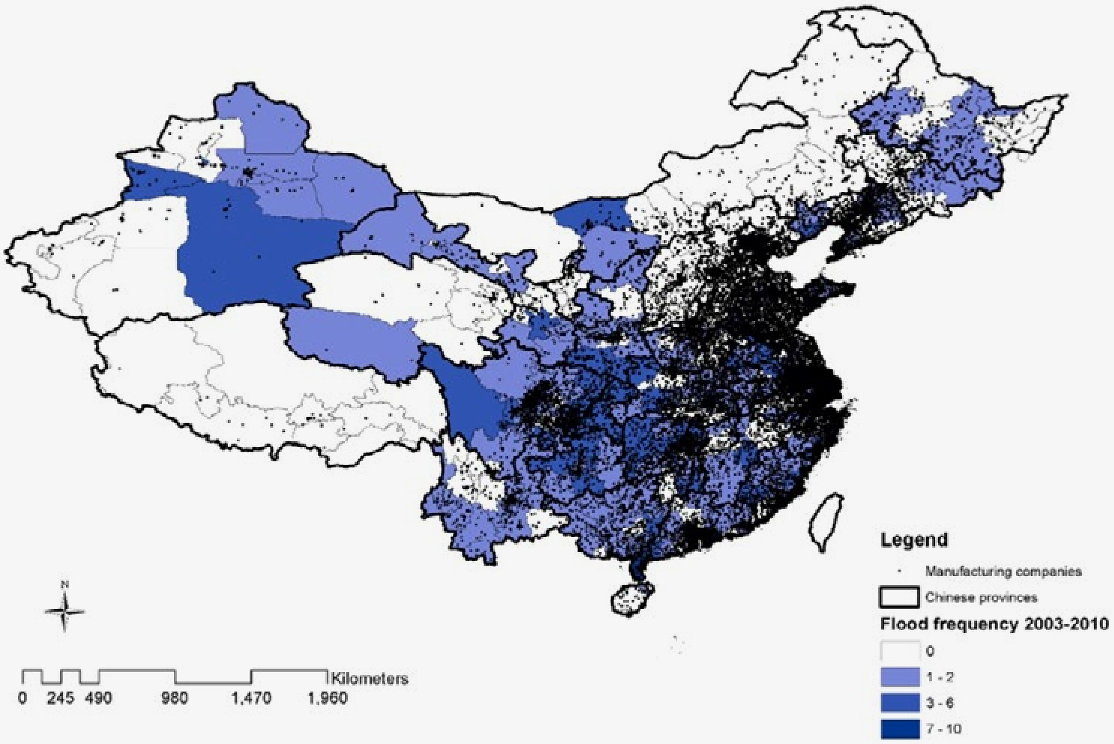
China is the world's leading manufacturer, accounting for 20% of global output in 2018, valued at US$2.1 trillion (Brookings, 2018). However, between 1998 and 2017, it sustained US$492.2 billion in absolute losses due to climate-related disasters (CRED & UNISDR, n.d.). Floods were the most frequent weather event, representing 43% of recorded events (CRED & UNISDR, n.d.). As the global temperature continue to rise, China's economy is expected to be hit hardest: from 2016 to 2035, direct losses as a result of flood events will cost an estimated US$389 billion, with indirect losses coming in at around US$90 billion (Willner *et al.*, 2018).

Such impacts are already being seen. In 2021, for example, severe floods in central China submerged the manufacturing hub of Zhengzhou, killing at least 69 people and disrupting industrial operations (New York Times, 2021). Japanese carmaker Nissan was forced to suspend production at its Zhengzhou facility, while China's largest auto-manufacturer, SAIC Motor, also experienced impacts on its logistics (Reuters, 2021c). Government estimates put losses associated with this flooding event at US$186 million. Economic losses from this flood across all sectors totalled US$19 billion, of which only US$2.3 billion was insured (Swiss Re, 2022, via SCMP, 2022). Zhengzhou is the capital of the Henan Province and sits on the banks of the Yellow River, making it extremely vulnerable to the effects of rising global water levels.

Other major rivers in China also threaten critical surrounding areas for economic development. Two-fifths of China's GDP is generated along the Yangtze River, for instance, which experienced its highest ever recorded water levels in 2020 (CGTN, 2020; Wei *et al.*, 2020). The economic zone around the Pearl River is similarly important, generating 20% of Chinese GDP. However, the combinations of its proximity to the coast and its low-lying topology means two of its biggest cities and manufacturing hubs—Guangzhou and Dongguan—are very susceptible to the effects of rising sea levels (Maplecroft, 2020).

From 2003 to 2010, major flooding events caused an estimated 12.3% annual loss in total output for manufacturing firms in China. Lagged flood effects led to an additional 2.3% total output loss (Hu *et al.*, 2019).

Figure 24: Locations of major reported flooding events at the city level between 2003 and 2010 and manufacturing companies in China (Dartmouth Flood Observatory, 2016; ORBIS, 2017)



5. Physical risk guidance

Key physical risk questions for financial institutions to consider

1. **Gathering information**
   - What are the most prevalent physical risks across our portfolio footprint?
   - What have our clients disclosed in their financial, sustainability, and climate reports regarding their physical risks?
   - How many of our clients have business resiliency plans?
   - Do we have locational data on the major assets of our clients?

2. **Assessing the risks**
   - How much of our portfolio operates in areas of high physical risk?
   - What does our exposure to higher-risk assets look like? What are the terms of our financial relationship (e.g. debt/equity, tenor)?
   - Have we looked at physical risk scenarios to see how those risks will evolve over time? Have we considered short-term, medium-term, and long-term risks?
   - How would physical hazards disrupt our clients' production and distribution activities?
   - How long might disruption last? What might be the potential loss in revenue?
   - What indirect damages might result from physical hazards (e.g. business disruption, changes in value of assets)?
   - How might insurance markets (and insurability) change in the face of worsening physical risks? What proportion of our clients are covered? Which hazards are covered? Is uninsurability a risk in areas of more frequent physical hazards?
   - Have we explored if local adaptation measures are being taken and, if so, how they will increase the resilience of assets to climate change?
   - How much are clients investing in adaptation and resiliency measures?

3. **Engaging with clients and updating strategy**
   - Do our senior leaders understand the physical risks of our clients?
   - How are we helping our clients to transition to more resilient infrastructure, equipment, and other assets?
   - How will the physical risks identified and assessed influence our strategy in the industrials sector?
   - What specific updates to risk management practices or business activities will be needed to appropriately consider these physical risks in our operations?

Recommendations for risk management

1. **Use highly granular location data to identify key physical hazards**
   - As climate data have advanced, financial institutions have access to a wide range of asset-level datasets. Many of these datasets are supplied by commercial third parties, but a wealth of open-source tools also exists. Asset-level information can include asset type, residual life, capacity, geographical and geolocational data, asset prices, and resiliency of assets. Financial institutions should have a clear knowledge of the major capital assets of their industrials clients. This includes knowledge of their locations, the hazards they are exposed to, existing insurance coverage, and any mitigating or exacerbating risk factors. Periodic analysis should be conducted on these assets by the financial institution or its client. This ongoing monitoring should establish the magnitude of the risks as well as any changes in risk levels over time. As a next step, this information can be combined with asset-specific data about mitigating and exacerbating factors (e.g. managing productivity with heat stress, alternative transport links, flood barriers). As suggested in the TCFD's guidance, financial institutions should conduct scenario analysis and explore their own exposures and resiliency under different conditions.
2. **Understand insurance coverage and review resilience plans**
   - Financial institutions should review the sections of client annual reports and climate-related financial disclosures focused on physical risks and resilience. Beyond this, financial institutions should request information on the adaptation measures being undertaken for both major capital assets and for their client overall. These plans can be compared with national adaptation plans (NAPs) issued by governments as well as other suggested resiliency measures (e.g. those within the IPCC's latest assessment report). Furthermore, insurance coverage is a critical component in assessing the climate exposure of industry assets. Financial institutions with exposure to climate-sensitive assets need to be familiar with insurance markets and know the extent of coverage on each asset. Financial institutions should be aware of the evolution of insurance markets in the areas in which they operate and should work to identify potential risks of uninsurability. In many places, insurance coverage may be linked to government policies, changes to which can have implications for insurability and coverage.

Adaptive and mitigating actions of clients

1. **Resiliency planning**
   - As climatic conditions grow more severe, the infrastructure and global supply chains of the industrials sector are placed at an increasing risk. Firms can develop resiliency and adaptation plans for their most important sites as well as for their supply chains. These plans can begin with an assessment of current climate risks and asset vulnerabilities. They should also explore different climate scenarios that focus on how the frequency and severity of climate

risks may change over time. Resiliency planning should also create procedures for business units to respond to potential disruptions in upstream supply and downstream consumption. Clients of the industrials sector can focus on developing green infrastructure and payments for ecosystem services. They can also strengthen synergies among adaptation measures and other environmental issues, such as floods and droughts, water scarcity, biodiversity conservation, air quality, and resource efficiency.

2. **Climate-ready infrastructure**
   - Given the capital-intensity of the industrials sector, firms in the sector should invest in climate-ready assets that will stand up to worsening climate hazards. This begins in the planning process for new assets by enacting building standards that are not just appropriate for today's conditions, but also adequately take into account potential tail-risk events in the future. For existing infrastructure, retrofits and climate defences may be considered, such as sea walls and back-up power generation located on site. The most effective of these investments may be those that offer environmental co-benefits. Examples of projects that build resiliency while also supporting nature include the restoration of mangrove forests and wetlands. The diffusion of financial tools aimed at rewarding resilient enterprises or enterprises belonging to resilient industrial clusters will be beneficial in promoting adaptation actions in the Industry sector.

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