S&P Global

Sustainable1

Unpriced Environmental Costs

The Top Externalities of the Global Market

July 2024

CAPITALS COALITION

Acknowledgments

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S&P Global Sustainable1

S&P Global Sustainable1 is the central source for sustainability intelligence from S&P Global. Sustainable1 matches customers with the sustainability products, insights and solutions from across S&P Global's divisions to help meet their unique needs. Our comprehensive coverage across global markets combined with in-depth sustainability intelligence provides financial institutions, corporations and governments with expansive insight on business risk, opportunity, and impact as we work towards a sustainable future. Our data and well-informed point of view on critical topics like energy transition, climate resilience, positive impact and sustainable finance allow us to go deep on the details that define the big picture so customers can make decisions with conviction.

Capitals Coalition

Capitals Coalition is a purpose-driven global collaboration transforming the way decisions are made by including the value provided by nature, people and society. Capitals Coalition hosts an open, pre-competitive space for organizations to come together, share best practice, tackle collective challenges, co-create solutions and champion a systemic approach to addressing nature loss, climate change, sustainable development and social inequity. The Coalition sits at the heart of an extensive global network that has united to advance this approach. By working with many hundreds of global partners, Capitals Coalition accelerates momentum, leverages success, connects powerful and engaged communities and identifies the areas, projects and partnerships where transformational change for nature, people and economies can happen.

Glossary

Term, acronym or abbreviation	Meaning
Biodiversity	The variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.
Environmental damage cost	The monetary value representing negative environmental externalities to business and society for a particular impact, sector and/or region.
Direct operations	Business operations and activities conducted in sources or locations owned or controlled by the company.
Ecosystem services	The contributions of ecosystems to the benefits used in economic and other human activity.
EKPI	Environmental key performance indicator; category of environmental impacts developed by S&P Global Sustainable1 for appraisal of sectors and regions.
Externality	The indirect impact of an economic activity affecting third parties not directly involved in the activity, and not reflected in market prices.
Human capital	The knowledge, skills, competencies and attributes embodied in individuals that contribute to improved performance and wellbeing.
Impact ratio	Environmental damage costs per unit of monetary output (revenue). An impact ratio above 1.0 indicates the environmental damage cost is greater than the associated revenue.
Indirect operations	Business operations and activities within the company's value chain that occur at locations or sources owned or controlled by another entity.
Natural capital	The stock of renewable and non-renewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people.
Produced capital	The human-made goods and financial assets that are used to produce goods and services consumed by society.
Sector-region	A business activity within a particular geographic region. Regions have been defined based on the United Nations continental sub-regional definitions.
Social capital	The networks, together with shared norms, values and understanding that facilitate cooperation within and among groups.

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1. Foreword

Understanding the true value of our economic activity is critical for our shared future. This report takes a step toward this by estimating the global level of environmental damage costs of publicly listed companies which are otherwise invisible.

All companies depend on nature, yet they generate trillions of dollars in environmental costs that are not reflected in the market each year. These “hidden costs” represent a significant burden on society and the environment, impacting everything from air quality to biodiversity to social inequity.

This analysis offers a summary of these costs by sector, sector group and regional levels. It provides a look at the true magnitude of the challenge, estimating environmental negative externalities at $3.71 trillion in 2021 alone. By expressing these environmental impacts in monetary terms, this report advances upon the work of its predecessor by integrating disclosed information on environmental key performance indicators (EKPIs) and social and human capital issues. While this report highlights these capitals impacts, there is still room for further development, including by expanding the analysis to the entire value chain and expanding valuation to social and human impacts.

Overall, this report builds on efforts to integrate the value of nature, people and society into corporate decision-making. It reflects the increasingly recognized need for a more comprehensive estimate of the annual value of economic activity and encourages the development of policies and practices that internalize these externalities, leading toward a more sustainable and equitable future.

I encourage you to explore this report’s findings and participate in the ongoing effort to create a world where economic prosperity goes hand-in-hand with environmental and social well-being.

Mark Gough
CEO, Capitals Coalition

2. About this report

The world's listed companies depend on natural capital for their operations yet cause trillions of dollars in environmental costs that are not accounted for each year. These unpriced environmental costs go unrecorded by the companies that generate them, but they have real impacts on society, business and nature. Failing to ascribe monetary valuations to these costs effectively hides them from policymakers, investors and consumers.

In this report, we estimate the environmental costs produced by publicly listed companies around the world, as represented by the S&P Global Broad Market Index (BMI). We analyze these costs through several lenses:

- Impact, also referred to as environmental key performance indicators (EKPIs).
- Sector and sector group.
- Geographic region.

This report also provides analysis of nature dependency risks, through the lens of each company's reliance on ecosystem services around the world, and important social and human capital issues that contextualize these environmental costs across multiple capitals.

The result of this analysis is a detailed overview of individual environmental damage costs at the impact, sector and region level. We find that, in aggregate, this universe of companies generated **at least $3.71 trillion in environmental negative externalities in 2021 — equal to more than 4% of global GDP** that year. In particular, the 100 largest of these externalities are environmental damage "hotspots" that are having the largest impact on society. By expressing these companies' environmental impacts in monetary terms, this report aims to provide decision-useful information to investors and other actors in the capital markets seeking a more complete view of the full costs — and potential risks — of the business activities in which major companies engage.

Company universe

The analysis is based on the S&P Global Broad Market Index (BMI), which includes more than 14,000 publicly listed companies from across dozens of developed and emerging markets. This analysis reviewed more than 12,000 of these companies representing 98% of the S&P Global BMI weight and over $58 trillion in annual revenues.

It takes a different approach than its predecessor report, *Natural Capital at Risk: The Top 100 Externalities of Business* (2013), which looked at estimated environmental costs across the global economy using aggregated regional sector revenues.

By focusing on listed companies, this study builds on and advances the findings of the predecessor report by:

- Integrating disclosed information on environmental key performance indicators (EKPIs) as well as social and human capital related issues where it is available.
- Making the results more actionable for companies that are looking to identify, measure and value their impacts and dependencies on natural, social and human capital.
- Providing a useful benchmark to measure and monitor corporate sustainability performance over time.
- Making the environmental cost valuation more relevant to investors seeking to understand risks and opportunities and inform capital allocation decisions across an investable universe of companies.

Scope of the analysis

This study focuses on the direct operations of companies and does not include their upstream or downstream impacts. This decision was taken for several reasons:

1. **Avoid issues of double counting:** Since the S&P Global BMI is a large global benchmark covering all sectors of the global economy, it is likely that one company's operational impacts would also be present in the supply chain of another company in the same universe.
2. **Focus on operational control:** This study aims to draw attention to the impacts that are under the direct operational control of each company, and which may be easier to mitigate in the future.
3. **Address issues with disclosure:** There is currently a lack of robust and consistent corporate disclosure on upstream and downstream value chain impacts, and more uncertainty in the estimation approaches that are used to fill gaps in disclosure.

However, limiting this analysis to the direct operations of listed companies excludes the environmental costs generated in company supply chains, which can be substantial for some sectors. This approach has a particularly noticeable impact on agriculture and land use. For example, land use is the third-largest category of damage cost, but it is significantly smaller than the damage costs from greenhouse gases (GHGs) and air pollution. The damage costs associated with GHGs, in particular, represent a larger proportion of total costs in the scope of this study than if indirect land use costs were included.

Natural, social and human capital

While the primary focus of this report is on natural capital through the measurement and monetary valuation of environmental costs, the analysis also includes information on some important social and human capital issues for companies operating in different sectors and geographies around the world. Social and human capital issues are assessed in this report using quantitative and qualitative valuation techniques as opposed to monetary valuations, and as a result, it may be difficult to compare them to natural capital issues in terms of their relative size and importance. Monetary valuations across all capitals may be applied in future iterations of this study, but the approaches taken for the measurement of all capitals align with the existing guidance provided by the Natural, Social and Human Capital Protocols.

3. Executive summary

The world's largest companies depend on natural capital for their operations yet cause trillions of dollars in environmental costs that are not accounted for each year. Hidden environmental costs represent some of the most significant negative externalities in the global economy — the indirect impact of economic activities affecting third parties not directly involved in the activities, and not reflected in market prices. Familiar examples of these negative externalities are widespread, from air pollution in dense city centers causing respiratory disease to industrial waste discharged into rivers and streams damaging aquatic ecosystems. While regulatory and investor pressure has led some sectors in different regions to address their environmental externalities, many remain unaccounted for around the world. The largest of these is anthropogenic global warming caused by greenhouse gas (GHG) buildup in the atmosphere, which scientists have linked to increasingly destructive weather patterns and rapid biodiversity loss globally.

This report seeks to identify and estimate the largest environmental externalities generated by publicly traded companies globally, as represented by the S&P Global Broad Market Index (BMI). By assigning a monetary value to these externalities at a sector and regional level, this report contributes to efforts to measure natural capital in economic terms that resonate with capital markets participants. In doing so, this analysis can help investors, policymakers and other stakeholders more accurately measure the full costs of sectors and business activities in specific regions: not only the materials, labor, taxes and other operating costs contained in financial statements but also the equally real costs to nature and human health. This report also provides analysis of nature dependency risks and important social and human issues that contextualize these environmental costs.

This study finds that:

- Companies in the S&P Global BMI were responsible for $3.71 trillion in unpriced environmental costs across their direct operations in 2021 — equal to more than 4% of global GDP that year.
- More than 26% of companies in the S&P Global BMI generated unpriced environmental costs larger than their net income.
- Greenhouse gas (GHG) emissions were responsible for the majority of unpriced environmental damage costs (63.6%) for these companies, followed by air pollution (26.2%) and land use (4.7%). The impacts of generating electricity from fossil fuels — particularly coal — represented the largest source of environmental costs globally.
- S&P Global BMI companies in the crop cultivation and livestock sector groups have high dependency on ecosystem services, but also generate the majority (57%) of land use-related environmental damage costs.
- Companies in some regions are taking steps to address their responsibility for human and social capital through commitments to protect human rights, but these commitments don't always cover a company's full supply chain.

The scale of the environmental damage costs estimated in this report underscores their potential materiality for the world's publicly traded companies, especially as pressure grows from investors, regulators and the public to measure and mitigate these costs. Disclosure frameworks — notably the final recommendations from the Taskforce on Nature-related Financial Disclosures (TNFD) released in September 2023 — for natural capital impacts and ecosystem service dependencies are gaining momentum as more stakeholders in the business world come to view action on climate change and nature in tandem.

For companies, this means that the work of measuring these costs, locating assets or operations that are major drivers of environmental damage, and evolving business practices to mitigate the costs could shift from a voluntary best practice to expected — or even mandatory — components of risk management in the coming years.

For investors, the findings of this analysis provide a more complete view of the potential risks inherent in certain business activities in specific regions, particularly those with high impact ratios. These activities may face more scrutiny in the coming years if climate and environmental policymaking ramp up to meet major international targets such as the Paris Agreement on climate change, the UN's Sustainable Development Goals, or the Global Biodiversity Framework.

For policymakers, these findings suggest that significant harm to nature and society can be avoided by accelerating the energy transition away from fossil fuels. While coal remains a cheap fuel source for power generation in much of the world, that market price does not reflect coal's hidden costs. All the activities examined in this study generate some level of environmental damage costs; addressing the costliest ones would have the greatest benefit to society and nature.

4. Report structure

This report organizes environmental damage costs into six **impacts**, also referred to as environmental key performance indicators (EKPIs): GHGs, air pollution, land use, waste, water and land pollution, and water use. The monetary value of these impacts is referred to as the **environmental damage cost**, which is measured at the level of economic sector and geographic region. The resulting list of individual environmental damage costs at the impact, sector and region level yields a list of the 100 largest environmental externalities produced by companies in the S&P Global BMI: a list of environmental damage cost "hotspots" that are having the largest impact on society.

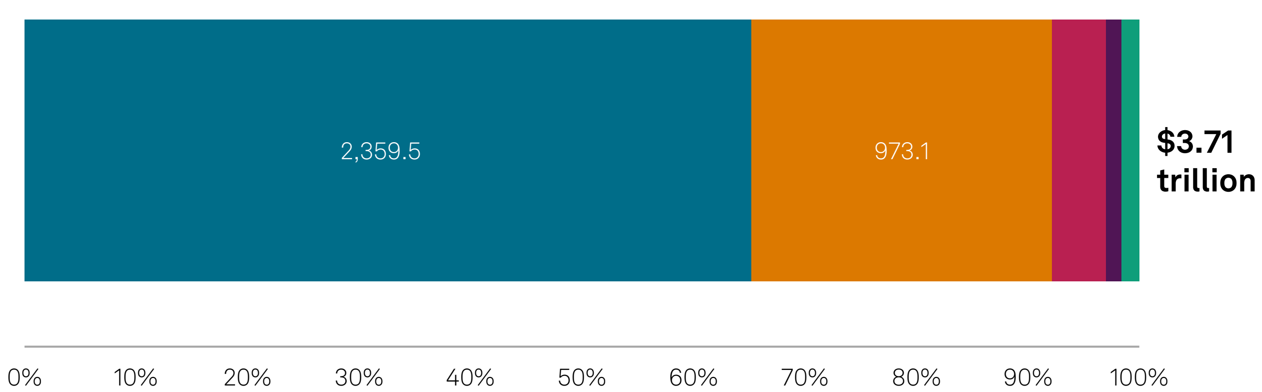
At an aggregate level across this universe of companies, 63.6% of environmental damage costs come from GHGs, followed by air pollution (26.2%) and land use (4.7%). These costs are not spread evenly around the world. With impacts from GHG emissions and air pollution generating the majority of environmental damage costs, the parts of the world where fossil fuel use remains high represent a large share of environmental damage costs on a regional basis. Eastern Asia, Southern Asia and Southeastern Asia in 2021 collectively represented 66.5% of the total environmental damage costs globally, while Northern America represented the second-highest environmental damage costs overall ($540.2 billion).

The largest contributing sectors and regions for each EKPI will be discussed in more detail. The methodologies underlying the valuation calculations for each EKPI can be found in Appendix 2.

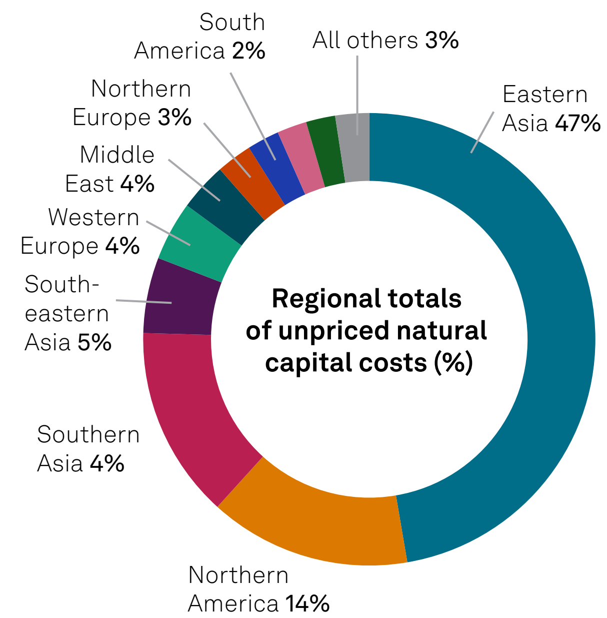
The environmental damage costs estimated in this report are attributed to 30 sector groups, which are composed of sectors defined by business activities. The fossil fuel electric power generation sector group, for example, includes sectors specific to coal, natural gas and oil-based power generation. The six largest sector groups by environmental damage costs — fossil fuel electric power generation, manufacturing of primary materials, mining and quarrying, transportation, crop cultivation, and livestock production — represent the vast majority (92.4%) of the total across all 30 sector groups and will be examined in further detail.

GHGs and air pollution represent 90% of unpriced natural capital costs for studied companies

Environmental damage cost by impact type for S&P Global BMI companies in 2021



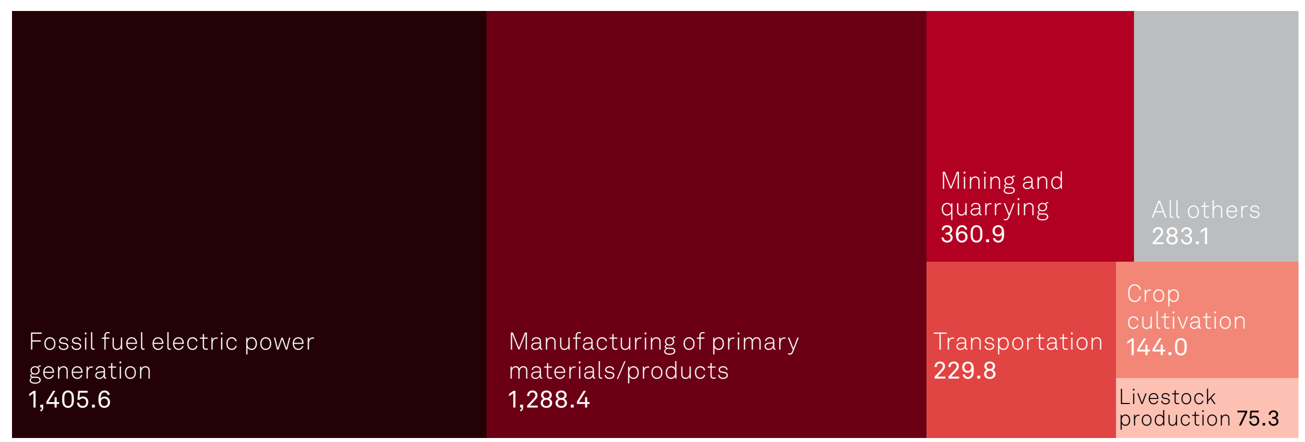
Source: S&P Global Sustainable1.



Source: S&P Global Sustainable1.

Region	Damage cost ($B)
Eastern Asia	$1,758.30
Northern America	$540.23
Southern Asia	$506.74
Southeastern Asia	$203.36
Western Europe	$151.21
Middle East	$126.12
Northern Europe	$93.20
South America	$86.74
Eastern Europe	$76.79
Southern Europe	$77.17
Australia and New Zealand	$36.02
Central America	$22.52
Southern Africa	$8.10
Western Africa	$6.43
Northern Africa	$4.99
Eastern Africa	$3.95
Central Asia	$3.74
Caribbean	$2.51
Central Africa	$2.10
Melanesia	$0.65
Western Asia	$0.56
Polynesia	$0.01
Micronesia	$0.01
	$3,711.46

Top 6 sector groups by damage cost ($B)



Source: S&P Global Sustainable1.

5. Methodology highlights

Our analysis examines more than 100 direct environmental impacts that companies may be responsible for within their own direct operations and groups them into six environmental impact categories, or environmental key performance indicators (EKPIs). The six EKPIs are GHGs, air pollution, land and water pollution, land use, water use, and waste. A more detailed methodology for each EKPI, as well as the other datasets used in this report, is included in Appendix 2.

- Environmental damage costs from **GHGs** assessed in this report reflect their contribution to global warming as well as expected climate change-related impacts to society and economies. The valuation of the impacts is calculated by multiplying companies' estimated GHGs by the social cost of carbon value determined in 2016 by the US Interagency Working Group on the Social Cost of Greenhouse Gases. The social cost of carbon values the marginal cost of each additional metric ton of GHG emitted in the atmosphere and over their lifetime, usually expressed in carbon dioxide equivalent (CO2e).

- **Air, land and water pollution** environmental damage costs reflect the impact of organic, heavy metal and other inorganic pollutants on human health and on ecosystems.

- **Land use** environmental damage costs include the estimated loss of ecosystem services caused by the conversion of land from its natural ecosystem to an alternative land use or state.

- **Water use** environmental damage costs involve multiple factors such as the expected costs of using water when supplies are scarce in a particular region as well as the impacts on terrestrial ecosystems and human health, given reduced freshwater availability.

- The calculation of **waste** environmental damage costs includes hazardous, non-hazardous, and nuclear waste, and their respective contributions to climate change, air pollution, as well as negative impact on human health.

The impact ratio calculated in this report is an indicator of whether the natural capital costs of an impact in a given sector-region outweighed the revenue generated by that economic sector.

For information on social and human issues, this report draws on the S&P Global Corporate Sustainability Assessment (CSA). The CSA gathers both public and private data via industry-specific questionnaires. On average, 23 sustainability topics are covered across 110 questions. About 10,500 of the companies in the S&P Global BMI were assessed in the 2022 CSA cycle.

Analysis of the nature dependency risks facing the sector groups in this report is based on the S&P Global Sustainable1 Nature & Biodiversity Risk Dataset, which applies the Nature Risk Profile Methodology for analyzing companies' impacts and dependencies on nature launched by S&P Global Sustainable1 and the UN Environment Programme in January 2023.[1]

The nature dependency scores are ranked on a scale from 0 to 1, with a score of 0.2 indicating a very low dependency, while a score of 0.8 indicates a high level of dependency.

This analysis also illustrates these sector groups' exposure to biodiversity risk by locating company assets that overlap with Key Biodiversity Areas (KBAs) around the world. KBAs are sites contributing significantly to the global persistence of biodiversity, identified at the national, sub-national or regional level by local stakeholders based on standardized scientific criteria and thresholds.

6. Background

Many of the environmental impacts on natural, human and social capital are not priced into the operations of companies. Instead, they manifest as negative externalities on society and nature, ultimately creating both short- and long-term risk for companies.

Natural capital refers to the stock of renewable and nonrenewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people. It also refers to the ecosystem services that society and companies depend on to modulate the earth's climate and hydrological, ecological and soil processes. Human capital refers to the knowledge, skills, competencies and attributes embodied in individuals that contribute to improved performance and wellbeing, while social capital refers to the networks, together with shared norms, values and understanding that facilitate cooperation within and among groups.

Human communities and natural ecosystems bear these costs in different ways, from direct harm caused by air and water pollution to the increasingly dangerous physical hazards of climate change driven by GHGs. These intersecting impacts on natural, human, and social capital demonstrate the need for companies to begin accounting for the external costs they generate.

6.1 Natural capital

The global economy depends on nature even as it is driving nature loss, which is reducing nature's ability to sustain those ecosystem services. Yet nature, which directly underpins the global economy, is only a nascent priority for many companies.[2]

About $44 trillion of global economic value generation — over half of global GDP in 2019 — is moderately or highly dependent on natural assets and their ecosystem services, according to the World Economic Forum.[3] An analysis PwC released in April 2023 updated that figure, finding that 55% of global GDP, equivalent to an estimated $58 trillion, is moderately or highly dependent on nature.[4]

As for the companies reviewed in this report, S&P Global Sustainable1 data has shown that 54% of companies in the S&P Global BMI are significantly dependent on nature across their direct operations.[5]

In 2021, companies in the S&P Global BMI used an estimated 370.8 million hectares of land for their direct operations — such as for farms, factories, mines, retail stores, hospitals and even office space. Companies' operations also often cross into some of the world's most important areas for biodiversity, known as Key Biodiversity Areas (KBAs). KBAs are sites deemed by the scientific community as contributing significantly to the global persistence of biodiversity. The KBA designation does not carry legal protection, but many KBAs overlap with protected areas such as national parks or wildlife reserves. S&P Global data shows that 16% of companies in the S&P Global BMI have at least one asset located in a KBA,[6] which could be exposed to increased regulation in the future.

One of the metrics reviewed in this report, land use, is the top EKPI for crop cultivation and livestock production, as well as several other sector groups outside the top six this report focuses on. Land use is the third-highest impact for the mining and quarrying sector group and the transportation sector group. Land use also accounted for four of the top 100 environmental impacts by sector and region: the cultivation of oilseeds in Eastern Asia and Southeastern Asia, the extraction of crude petroleum and natural gas in Northern America and pig, sheep and other animal production in Eastern Asia.

6.2 Human and social capital

Human and social capital also underpin the global economy, and unpriced environmental impacts can have significant costs for human health and wellbeing, both at the individual level and on the scale of communities.

Some of the largest environmental impacts identified in this report cause direct harm to human health, thus creating significant human capital costs. Air pollution, which is the second-largest impact generated by companies in the S&P Global BMI in this report, increases the risk of strokes, heart and lung disease, cancer and other respiratory diseases such asthma, according to the World Health Organization. The WHO estimates that air pollution is associated with 6.7 million premature deaths each year, the vast majority of which occur in low- and middle-income countries.[7] And the World Bank in 2022 found that air pollution accounts for more than $8 trillion in health costs each year, equivalent to about 6.1% of global GDP.[8]

Human and social capital often intersect, as the strength of communities, networks and shared values depends on human health and wellbeing. This is particularly apparent from the perspective of corporate supply chains, in which raw material extraction or production may be occurring alongside local communities that bear the environmental costs. These communities may also face unfair treatment in terms of land acquisition, displacement or labor practices. These interactions with companies can directly affect the health and wellbeing of the individuals in these communities, affecting the group's social cohesion. This report will discuss this aspect of harm to social capital by examining corporate commitments to human rights and local and Indigenous community engagement.

6.3 Growing regulatory and investor pressure

Companies are coming under increased pressure from regulators, investors and their customers to measure, report and mitigate environmental impacts.

Scientists have found that the world is using more natural resources each year than the Earth can naturally replenish.[9] Pollution affects the health of communities and workforce productivity and climate change poses both physical and transition risks to businesses in the form of extreme weather events and patterns, new regulations and changing social and investor expectations. The UN's Intergovernmental Panel on Climate Change (IPCC) has warned that unless the world moves faster to reduce emissions, it will be locked into a global warming trajectory with exponentially higher losses and damage for businesses, nature and society.[10]

Investors want to know that companies are measuring and managing their short- and long-term risks associated with climate change, nature loss, supply chains and changing social dynamics and customer expectations.

Moreover, a number of voluntary and mandatory disclosure frameworks have been finalized or are under development around the world. The International Sustainability Standards Board (ISSB) in June 2023 issued its first two global sustainability disclosure standards designed to create a common framework for companies to disclose their climate-related risks.[11] The ISSB's next research projects will focus on nature and human capital.[12] The European Commission in July 2023 adopted corporate sustainability reporting standards that cover a range of topics including climate change, biodiversity and human rights.[13] The Hong Kong Stock Exchange proposed in April 2023 to make listed companies provide mandatory climate-related disclosures that would be based on the ISSB's climate standard.[14] And the US Securities and Exchange Commission in March 2024 finalized rules requiring many publicly traded companies to disclose certain climate-related information, though it issued a stay the following month to facilitate the resolution of legal challenges to the rules.[15, 16]

Companies also face the potential for governments to require them to internalize the costs of emissions through such mechanisms as carbon pricing or by creating a carbon levy on imports. The European Commission in August 2023 adopted rules for the implementation of its carbon border adjustment mechanism (CBAM), which imposes a carbon price on imports in the form of a levy.[17]

Companies' impacts on nature, including biodiversity loss through land use, is also rising on the agenda of investors and regulators following the passage of a new Global Biodiversity Framework at the UN's COP15 biodiversity conference in December 2022.[18] Under the framework, governments pledged to achieve "effective conservation and management of at least 30% of the world's lands, inland waters, coastal areas and oceans" by 2030. Target 15 of the Framework asks governments to require large companies to identify and disclose their dependencies and impacts on biodiversity. And the Taskforce on Nature-related Financial Disclosures (TNFD) in September 2023 finalized its framework for nature-related risk management and disclosures.[19]

All of these factors, coupled with increased awareness around environmental and social issues, mean that companies will come under increasing pressure to think holistically when crafting plans for reducing those impacts. Leading companies are adopting policies or making commitments to ensuring a just transition for decarbonization through workforce training and other programs; engaging with local and Indigenous communities on decisions affecting land and water use; and creating robust governance practices on human rights risks.

7. The rankings

Ranking of the 100 largest environmental impacts in the S&P Global BMI measured in monetary terms

Rank	Impact	Sector	Region	Damage cost ($B)	Revenue ($B)	Impact ratio
1	GHGs	Production of electricity by coal	Eastern Asia	385.6	163.0	2.4
2	Air Pollution	Production of electricity by coal	Eastern Asia	205.9	163.0	1.3
3	Air Pollution	Production of electricity by coal	Southern Asia	203.0	26.2	7.7
4	GHGs	Manufacture of cement, lime and plaster	Eastern Asia	163.6	138.9	1.2
5	GHGs	Manufacture of iron, steel and ferroalloys	Eastern Asia	162.0	524.8	0.3
6	GHGs	Production of electricity by coal	Northern America	88.3	43.4	2.0
7	GHGs	Production of electricity by coal	Southern Asia	83.9	26.2	3.2
8	GHGs	Mining and agglomeration of coal and lignite	Eastern Asia	71.8	180.9	0.4
9	GHGs	Production of electricity by gas	Northern America	63.1	71.1	0.9
10	GHGs	Manufacture of basic chemicals	Eastern Asia	53.6	458.1	0.1
11	GHGs	Production of electricity by gas	Eastern Asia	37.9	60.2	0.6
12	GHGs	Petroleum refining	Northern America	36.0	662.7	0.1
13	Air Pollution	Manufacture of iron, steel and ferroalloys	Eastern Asia	34.4	524.8	0.1
14	GHGs	Production of electricity by coal	Southeastern Asia	32.9	20.4	1.6
15	Land Use	Cultivation of oil seeds	Southeastern Asia	32.5	24.4	1.3
16	Water Use	Production of electricity by coal	Eastern Asia	32.4	163.0	0.2
17	GHGs	Extraction of crude petroleum and natural gas	Northern America	31.7	370.8	0.1
18	GHGs	Manufacture of cement, lime and plaster	Southern Asia	30.8	29.1	1.1
19	GHGs	Manufacture of iron, steel and ferroalloys	Northern America	30.0	184.1	0.2
20	GHGs	Manufacture of iron, steel and ferroalloys	Southern Asia	26.3	58.5	0.5
21	GHGs	Manufacture of cement, lime and plaster	Northern America	25.3	26.7	0.9
22	GHGs	Production of electricity by gas	Middle East	24.7	21.7	1.1
23	Land Use	Pig, sheep, and other animal production (incl. aquaculture)	Eastern Asia	24.4	31.4	0.8
24	GHGs	Petroleum refining	Eastern Asia	24.0	348.8	0.1
25	GHGs	Air transportation	Northern America	21.9	129.4	0.2
26	GHGs	Production of electricity by coal	Eastern Europe	21.5	13.0	1.6
27	Air Pollution	Manufacture of basic chemicals	Eastern Asia	21.0	458.1	0.0
28	GHGs	Extraction of crude petroleum and natural gas	Middle East	19.9	210.5	0.1
29	Air Pollution	Cultivation of oil seeds	Eastern Asia	19.4	22.2	0.9
30	GHGs	Manufacture of cement, lime and plaster	Southeastern Asia	19.1	12.1	1.6
31	GHGs	Water transportation	Eastern Asia	18.5	117.5	0.2
32	Air Pollution	Mining of copper ores and concentrates	Eastern Asia	18.5	78.6	0.2
33	Air Pollution	Manufacture of cement, lime and plaster	Eastern Asia	18.4	138.9	0.1
34	Air Pollution	Manufacture of iron, steel and ferroalloys	Southern Asia	17.7	58.5	0.3
35	GHGs	Production of electricity by gas	Southeastern Asia	17.0	19.4	0.9
36	GHGs	Manufacture of basic chemicals	Northern America	15.3	164.4	0.1
37	Air Pollution	Manufacture of cement, lime and plaster	Southern Asia	14.7	29.1	0.5
38	GHGs	Manufacture of aluminium	Eastern Asia	14.5	92.6	0.2
39	Air Pollution	Pig, sheep, and other animal production (incl. aquaculture)	Eastern Asia	14.5	31.4	0.5
40	GHGs	Petroleum refining	Middle East	14.4	257.4	0.1
41	GHGs	Extraction of crude petroleum and natural gas	Eastern Asia	14.4	127.0	0.1
42	GHGs	Air transportation	Eastern Asia	14.3	77.6	0.2
43	GHGs	Production of electricity by gas	Western Europe	13.8	37.4	0.4
44	Air Pollution	Mining of iron ores	Eastern Asia	13.7	122.0	0.1
45	GHGs	Petroleum refining	Southern Asia	13.3	186.5	0.1
46	Land Use	Cultivation of oil seeds	Eastern Asia	12.5	22.2	0.6
47	GHGs	Water transportation	Northern America	12.4	73.7	0.2
48	Air Pollution	Poultry farming and egg production	Eastern Asia	12.4	18.3	0.7
49	GHGs	Distribution and trade of electricity	Eastern Asia	12.2	135.8	0.1
50	Air Pollution	Mining of other non-ferrous metal ores and concentrates	Eastern Asia	12.1	76.6	0.2

Chart continued next page

Ranking of the 100 largest environmental impacts in the S&P Global BMI measured in monetary terms

Rank	Impact	Sector	Region	Damage cost ($B)	Revenue ($B)	Impact ratio
51	GHGs	Production of electricity by gas	Southern Europe	11.9	25.70	0.5
52	Air Pollution	Petroleum refining	Southern Asia	11.8	186.50	0.1
53	Air Pollution	Manufacture of aluminium	Eastern Asia	11.8	92.60	0.1
54	GHGs	Production of electricity by coal	Australia and New Zealand	11.7	5.50	2.1
55	GHGs	Manufacture of paper	Eastern Asia	11	61.10	0.2
56	GHGs	Manufacture of iron, steel and ferroalloys	Middle East	10.5	31.40	0.3
57	Land Use	Extraction of crude petroleum and natural gas	Northern America	10.5	370.80	0
58	GHGs	Production of electricity by gas	Northern Europe	10.4	24.50	0.4
59	Air Pollution	Mining and agglomeration of coal and lignite	Eastern Asia	10.4	180.90	0.1
60	GHGs	Manufacture of cement, lime and plaster	Western Europe	10.4	9.40	1.1
61	GHGs	Manufacture of iron, steel and ferroalloys	Western Europe	10.4	52.90	0.2
62	GHGs	Production of electricity by coal	Western Europe	10.3	14.40	0.7
63	Air Pollution	Manufacture of copper	Eastern Asia	10.2	117.30	0.1
64	GHGs	Manufacture of cement, lime and plaster	Middle East	10	8.70	1.2
65	GHGs	Manufacture of iron, steel and ferroalloys	South America	10	45.80	0.2
66	Air Pollution	Production of electricity by coal	Northern America	9.7	43.40	0.2
67	GHGs	Production of electricity by coal	Northern Europe	9.7	10.10	1
68	GHGs	Manufacture of paper products	Northern America	9.5	82.30	0.1
69	GHGs	Production of electricity by gas	South America	9.2	11.20	0.8
70	Air Pollution	Production of electricity by gas	Eastern Asia	9.1	60.20	0.2
71	Air Pollution	Production of electricity by coal	Eastern Europe	9	13.00	0.7
72	Air Pollution	Manufacture of paper	Eastern Asia	8.5	61.10	0.1
73	Air Pollution	Water transportation	Eastern Asia	8.3	117.50	0.3
74	Air Pollution	Mining of iron ores	Southern Asia	8.3	8.10	1
75	GHGs	Manufacture of basic chemicals	Southeastern Asia	7.8	61.50	0.1
76	GHGs	Manufacture of fertilizers, pesticides, and other agricultural chemicals	Eastern Asia	7.7	43.40	0.2
77	Air Pollution	Petroleum refining	Eastern Asia	7.7	348.80	0
78	GHGs	Wholesale and retail trade	Eastern Asia	7.7	2,743.30	0
79	GHGs	Petroleum refining	Southeastern Asia	7.6	97.90	0.1
80	GHGs	Pig, sheep, and other animal production (incl. aquaculture)	Eastern Asia	7.5	31.40	0.2
81	GHGs	Wholesale and retail trade	Northern America	7.4	4,139.40	0
82	GHGs	Petroleum refining	South America	7.1	75.00	0.1
83	Water Use	Production of electricity by hydro	Eastern Asia	7.1	56.80	0.1
84	GHGs	Mining and agglomeration of coal and lignite	Southern Asia	7	16.70	0.4
85	GHGs	Petroleum refining	Western Europe	6.8	144.40	0
86	GHGs	Manufacture of fertilizers, pesticides, and other agricultural chemicals	Northern America	6.5	47.60	0.1
87	GHGs	Production of electricity by biomass	Eastern Asia	6.4	6.60	1
88	GHGs	Manufacture of paper	Northern America	6.3	30.00	0.2
89	Air Pollution	Production of electricity by coal	Southeastern Asia	6.2	20.40	0.3
90	GHGs	Manufacture of basic chemicals	Western Europe	6.1	69.00	0.1
91	GHGs	Petroleum refining	Northern Europe	6	165.20	0
92	Air Pollution	Production of electricity by gas	Northern America	6	71.10	0.1
93	Air Pollution	Manufacture of aluminium	Southern Asia	6	8.50	0.7
94	GHGs	Manufacture of iron, steel and ferroalloys	Central America	5.9	17.00	0.4
95	GHGs	Petroleum refining	Southern Europe	5.9	91.60	0.1
96	GHGs	Pipeline transportation	Northern America	5.9	127.70	0
97	GHGs	Mining and agglomeration of coal and lignite	Southeastern Asia	5.8	17.30	0.3
98	GHGs	Manufacture of paper products	Eastern Asia	5.8	64.90	0.1
99	GHGs	Production of electricity by gas	Eastern Europe	5.8	11.40	0.5
100	Water Use	Production of electricity by nuclear	Eastern Asia	5.8	27.40	0.2

Source: S&P Global Sustainable1.

7.1 The top 100 environmental impacts by region and sector

In this analysis, the total sum of unpriced natural capital costs generated by the direct operations of S&P Global BMI companies in 2021 — $3.71 trillion — is the aggregation of nearly 18,000 specific environmental impacts generated by sectors in their respective geographic regions.

About $2.74 trillion, or 73.7%, of the total environmental damage costs come from just the top 100 of these environmental impacts by sector and region. The majority of these top 100 impacts are due to GHGs (68.8%), followed by air pollution (26.6%) and land use (2.9%).

However, environmental damage costs from the other three EKPIs of water use, waste, and land and water pollution still amount to tens of billions of dollars. Most of the environmental damage costs from the top 100 impacts by region and sector occurred in Eastern Asia (56.2%), followed by Southern Asia (15.4%) and Northern America (14.1%).

This analysis also includes the ratio of environmental damage costs to revenue generated by a given sector within a particular region. This impact ratio demonstrates whether the economic production (revenue) of that sector outweighs the hidden costs to the environment and human communities. For example, the third-highest impact in the top 100 — air pollution from the production of electricity by coal in Southern Asia — generated environmental damage costs of $203.0 billion in 2021, which was 7.7 times greater than the $26.2 billion in revenue generated by that sector in that region. Any impact ratio above 1.0 indicates that the environmental damage costs were greater than their associated revenue.

7.2 The top 20 sector-regions

The environmental damage cost from the six impacts can be aggregated at the level of sector and region to represent the full environmental damage cost created by that sector in that region. The 20 largest of these sector-regions generate combined environmental damage costs of $2.13 trillion, which equates to 57.4% of the $3.71 trillion in total environmental damage costs of the S&P Global BMI.

The production of electricity by coal; the manufacture of iron, steel and ferroalloys; the manufacture of cement, lime and plaster; petroleum refining; production of electricity by gas; and the cultivation of oilseeds are among the most damaging sectors globally. These sectors appear most frequently in the top 20 ranking.

The cultivation of oilseeds involves growing plants and trees and then using their seeds to produce edible oils, including vegetable oils, as well as proteins, fiber and biofuels. Oilseed sources include oil palm fruit, soybeans, sunflower seeds, canola, rapeseed and peanuts.

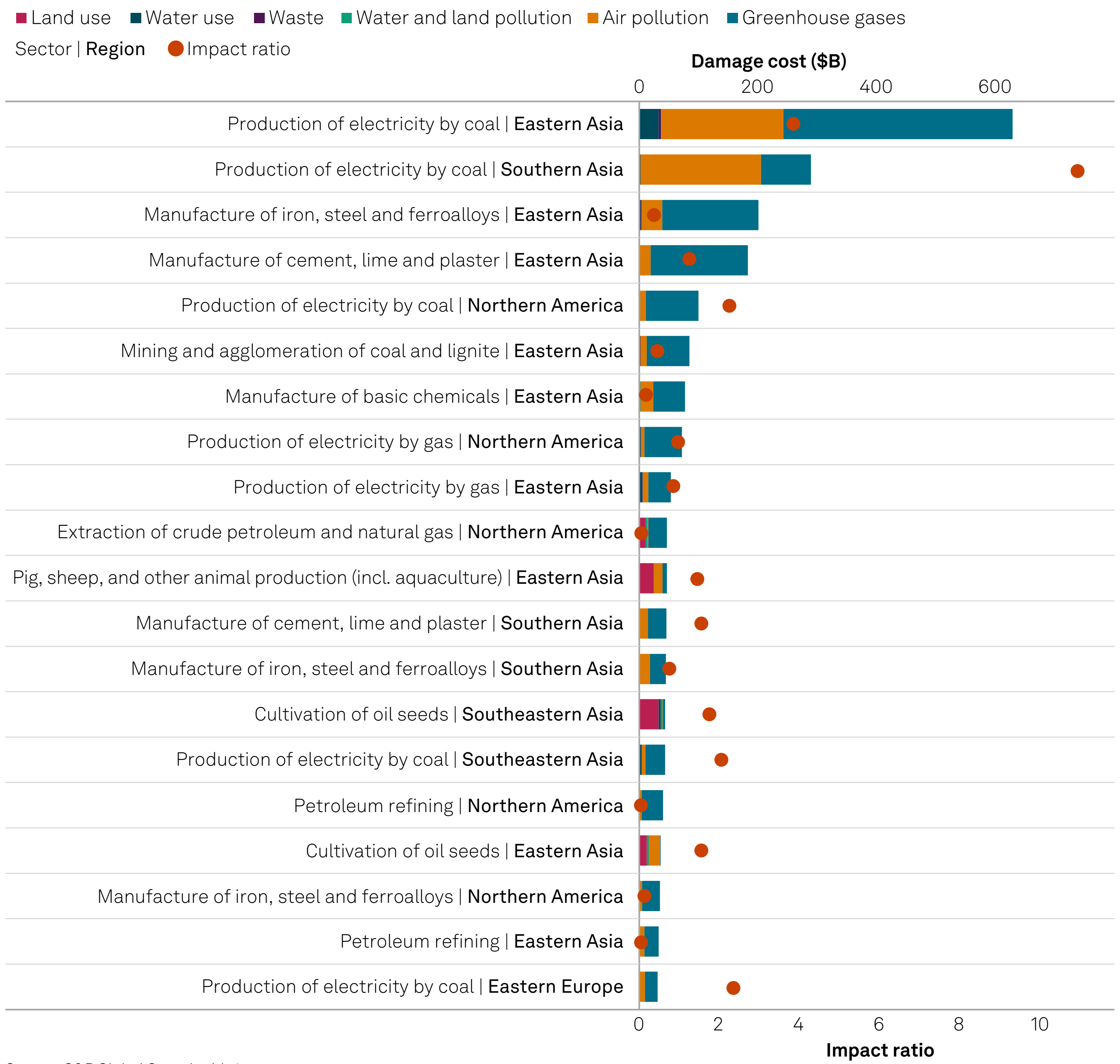
The environmental damage costs of the production of electricity by coal in Eastern Asia are higher than the same sector's costs in Southern Asia and Northern America. Environmental damage costs from the production of electricity by coal are higher in densely populated regions where coal has a large share of the power grid mix, due to the high emission of sulfur oxides (SOx) and their negative effects on human health. The next-highest environmental damage costs are driven by the manufacture of iron and cement in Eastern Asia, where the costs of GHGs and air pollution are high.

The high level of land use for the oilseeds cultivation sector contributes to biodiversity harm in Southeastern Asia, a region with many high-value ecosystems. Land use is also a major source of environmental damage costs for the pig, sheep and other animal production livestock sector in Eastern Asia.

Major environmental damage costs from Northern America primarily involve sectors related to fossil fuels. The fifth-highest sector-region — the production of electricity by coal in Northern America — is followed by electricity production by gas and the extraction of crude oil and natural gas in the top 20.

Environmental damage costs were higher than revenue for half of the top 20 sector-regions, reflected by an impact ratio greater than 1. This ratio was highest for the production of electricity by coal in Southern Asia, where the environmental damage costs were 11 times higher than sector revenue in 2021. The next highest impact ratio was 3.9, for the production of electricity by coal in Eastern Asia. All three agriculture-related sector-regions in the top 20 generated more environmental costs than revenue in 2021.

20 highest damage cost sector-regions



Source: S&P Global Sustainable1.

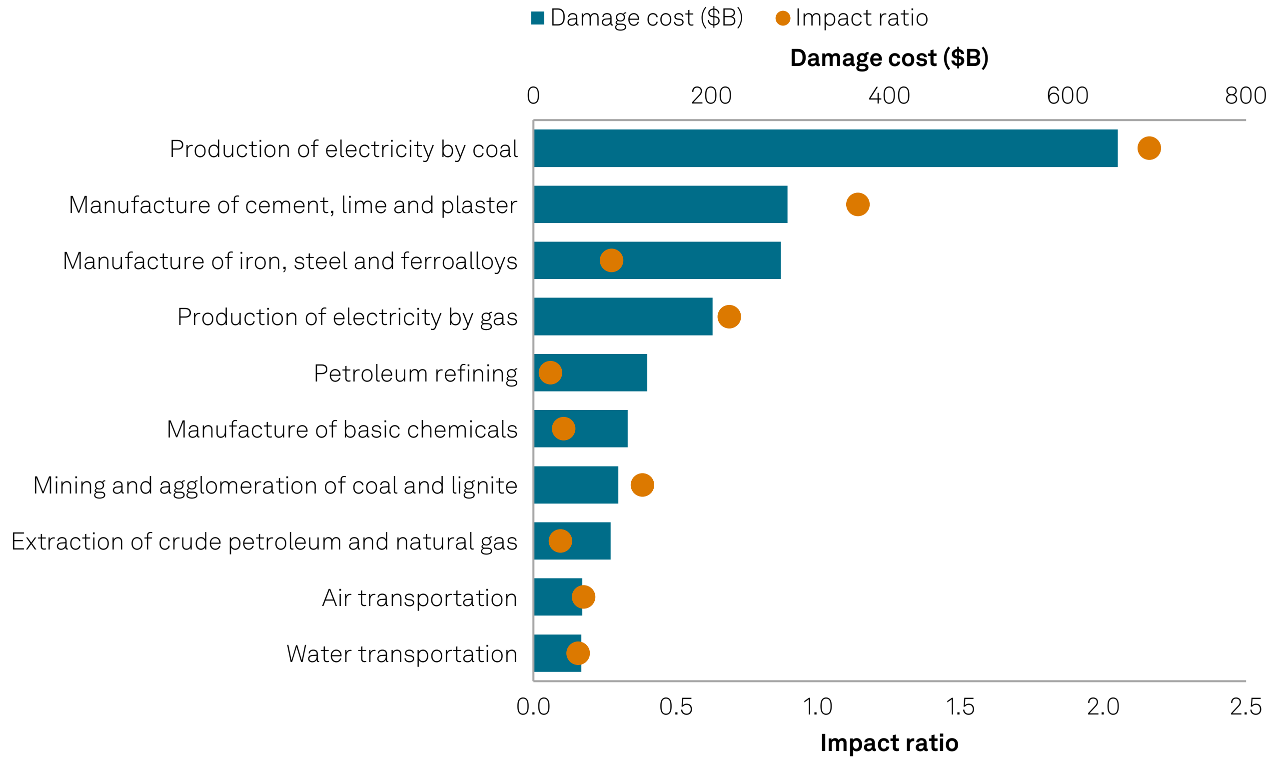
7.3 Highest environmental damage cost sectors by EKPI globally

This section reviews the 10 sectors generating the highest environmental damage costs globally for each of the EKPIs.

The production of electricity by coal causes the highest environmental damage costs across three of the six impacts: air pollution, GHGs and water use. As for the other three EKPIs, the cultivation of oilseeds sector is the most impactful for land use; the production of electricity by nuclear is the most impactful when it comes to waste; and water supply and sewerage is the most impactful sector for water and land pollution globally.

7.3.1 GHGs

10 highest damage cost sectors for greenhouse gases EKPI globally



EKPI = Environmental key performance indicator.
Source: S&P Global Sustainable1.

Increased concentration of GHGs has long-term impacts on society and economic outcomes, including changes in net agricultural productivity, human health, property damages from increased flood risk and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning.[20]

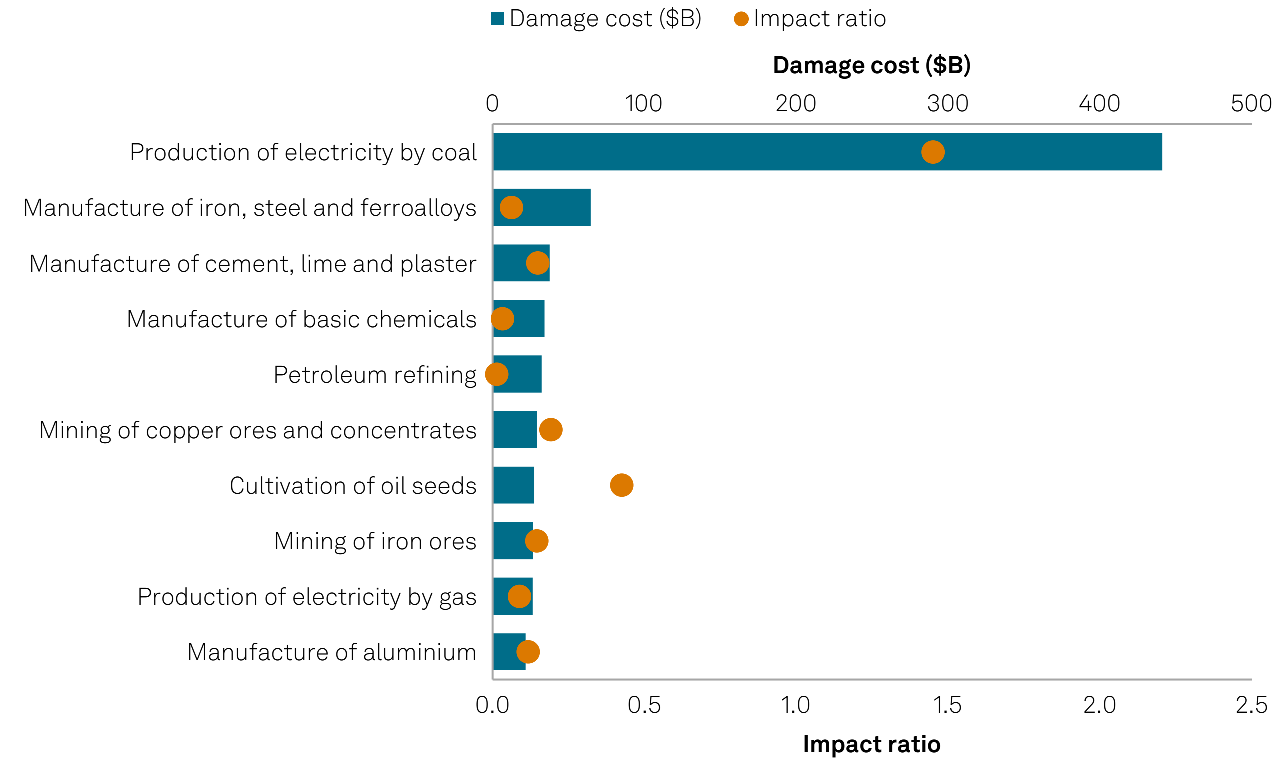
As the most significant sector for GHGs, the production of electricity by coal caused $656.1 billion in environmental damage costs in 2021. Moreover, the environmental damage costs of GHGs from coal electricity generation were 2.2 times greater than the sector's revenues in that year.

As detailed later in this report (8.2, Why coal-fired generation is so impactful), the production of electricity by coal produces high levels of CO_2 emissions. For example, the production of electricity by coal in 2021 in the US accounted for 59% of all CO_2 emissions yet represented only 23% of all electricity generated in the country, according to the US Environmental Protection Agency.[21]

Next, the manufacture of cement, lime and plaster generated $285.1 billion in environmental damage costs in 2021. This sector also had an impact ratio of 1.1 for total GHGs, meaning costs due to the GHGs impact alone were 1.1 times the sector's total global revenue for the year.

7.3.2 Air pollution

10 highest damage cost sectors for air pollution EKPI globally



EKPI = Environmental key performance indicator.
Source: S&P Global Sustainable1.

For air pollution, the production of electricity by coal has the highest total environmental damage costs of all sectors, and it is also the only sector that has an impact ratio above 1. The environmental damage costs of air pollution from the production of electricity by coal were almost 1.5 times greater than the sector's revenues in that year.

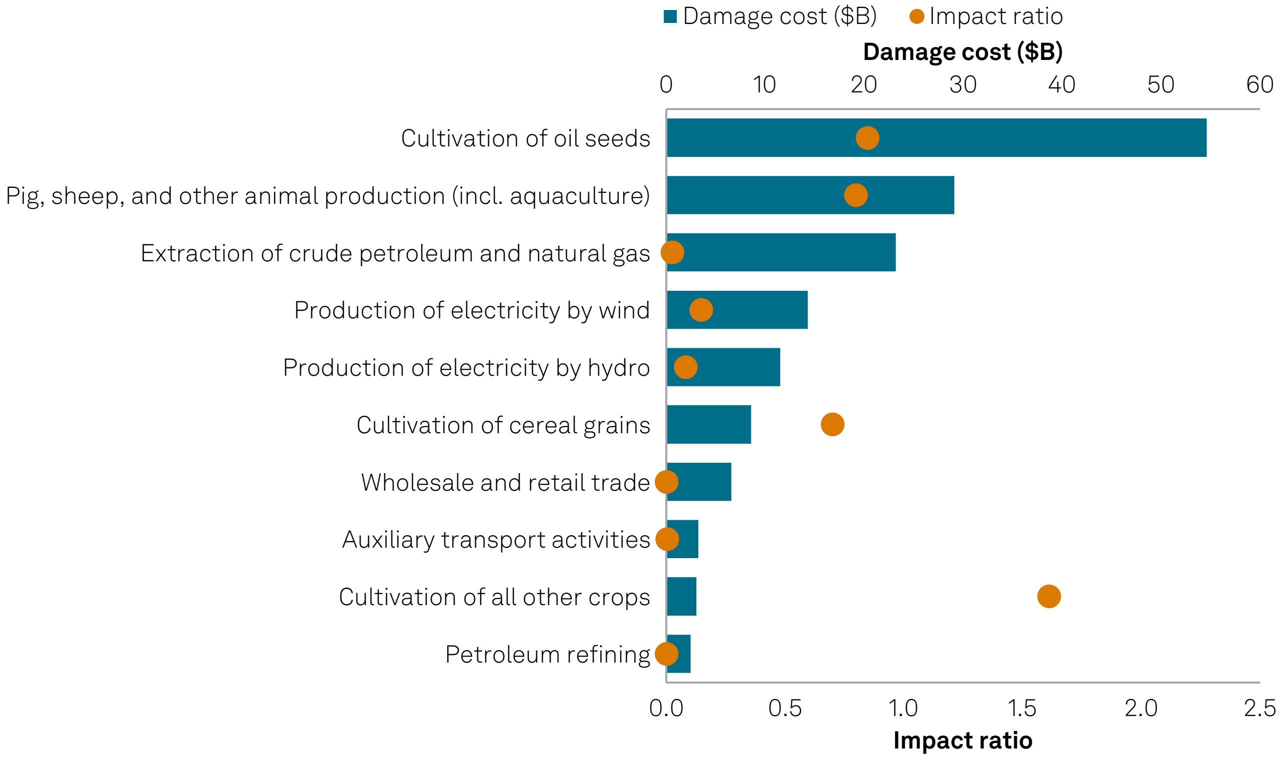
The air pollution environmental damage costs of the production of electricity by coal sector globally ($441.0 billion) were also 6.8 times greater than the second-highest sector for air pollution, which is the manufacture of iron, steel and ferroalloys.

Most of the top 10 sectors for air pollution are in the manufacturing, mining and quarrying, or fossil fuel electric generation sector groups. One notable exception is the cultivation of oilseeds, which is part of the crop cultivation sector group.

The manufacture of cement, lime and plaster had $37.7 billion in air pollution environmental damage costs. The fourth- and fifth-highest environmental damage cost sectors for air pollution were the manufacture of basic chemicals and petroleum refining.

7.3.3 Land use

10 highest damage cost sectors for land use EKPI globally



EKPI = Environmental key performance indicator.
Source: S&P Global Sustainable1.

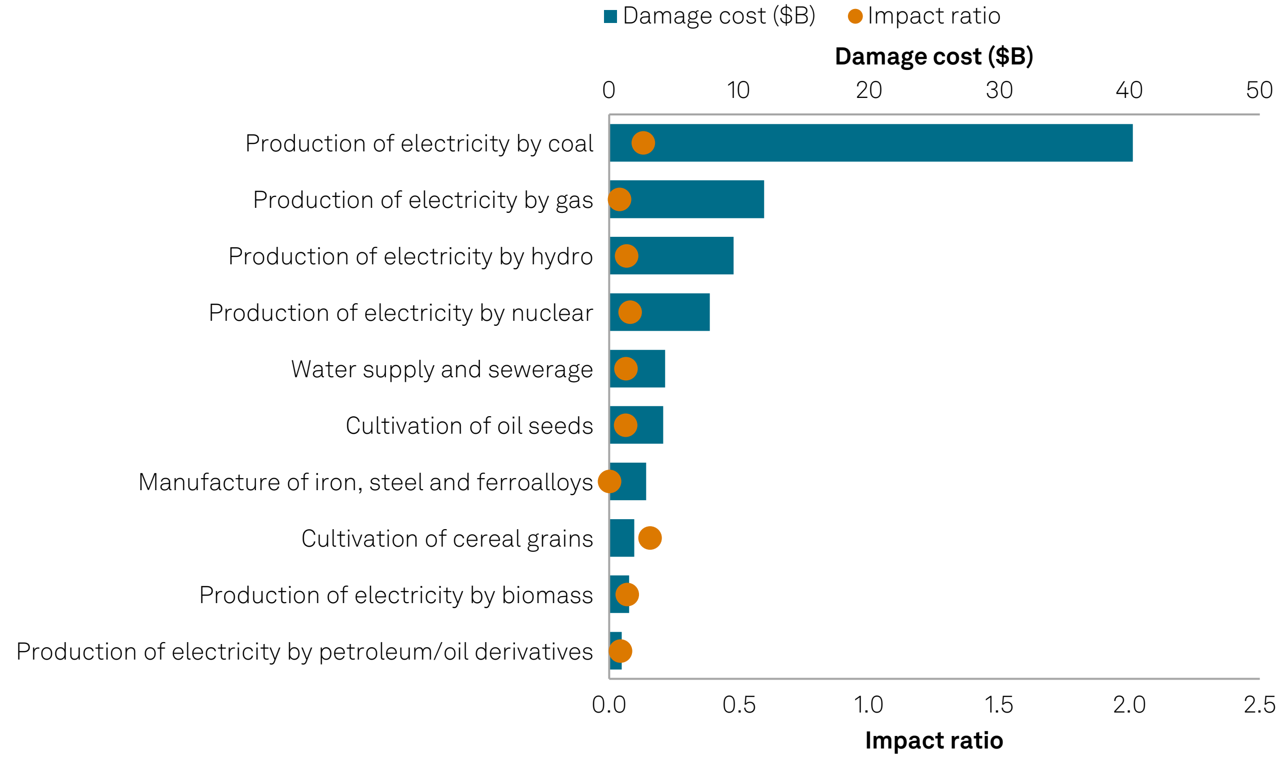
Sectors that have the highest environmental damage costs for the land use EKPI are those that inherently require more land for their operations, including for agriculture, livestock and energy infrastructure, as well as wholesale and retail trade.

The cultivation of oilseeds produced the highest environmental damage costs for land use of all sectors globally: about $54.6 billion in 2021. Other sectors within the crop cultivation sector group that had high land use costs include the cultivation of cereal grains and the cultivation of all other crops. The cultivation of all other crops also had an impact ratio greater than 1, which indicates the environmental damage costs for land use for that sector were greater than its revenues in 2021.

The second-highest environmental damage cost sector for land use was pig, sheep and other animal production: about $29.1 billion in 2021. The third-highest sector for land use globally was the extraction of crude petroleum and natural gas.

7.3.4 Water use

10 highest damage cost sectors for water use EKPI globally



EKPI = Environmental key performance indicator.
Source: S&P Global Sustainable1.

Six out of the top 10 highest environmental damage cost sectors for water use globally are involved in electricity production.

Electricity generated from natural gas and coal has the highest water use environmental damage costs across all sectors globally, which reflects the fact that power plants require water for cooling, to create steam and — for coal-fired plants — for handling waste ash and pollution control.

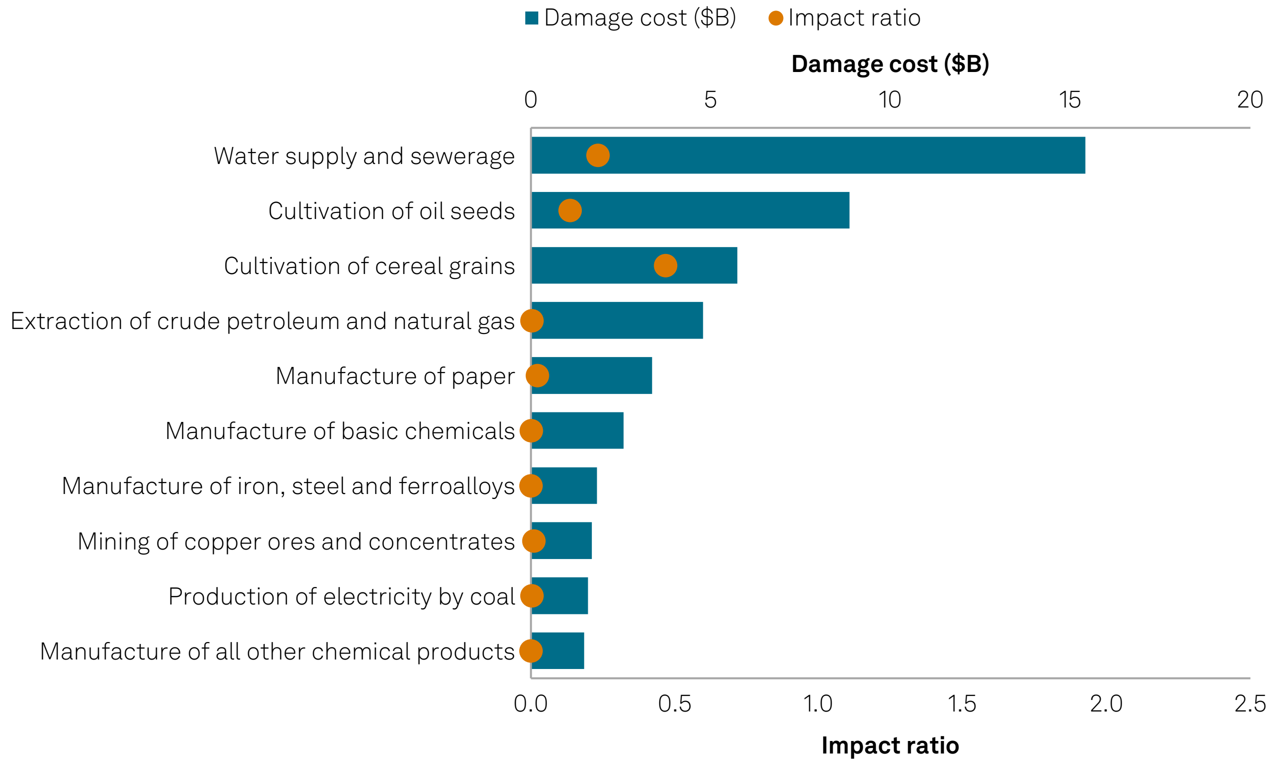
The water use environmental damage costs from the production of electricity by coal ($40.2 billion) were more than three times larger than for the production of electricity by gas ($11.9 billion).

The production of electricity by hydro, which requires the use of water run through turbines to generate electricity, had the third-highest environmental damage costs. And the production of electricity by nuclear, which requires water for cooling, was fourth.

Two sectors in the crop cultivation sector group on the top 10 list for water use are the cultivation of oilseeds and the cultivation of cereal grains. Both sectors require the use of water to produce crops, including through the use of irrigation systems. According to the Organisation for Economic Co-operation and Development, agriculture irrigation accounts for 70% of water use worldwide.[22]

7.3.5 Water and land pollution

10 highest damage cost sectors for water and land pollution EKPI globally



EKPI = Environmental key performance indicator.
Source: S&P Global Sustainable1.

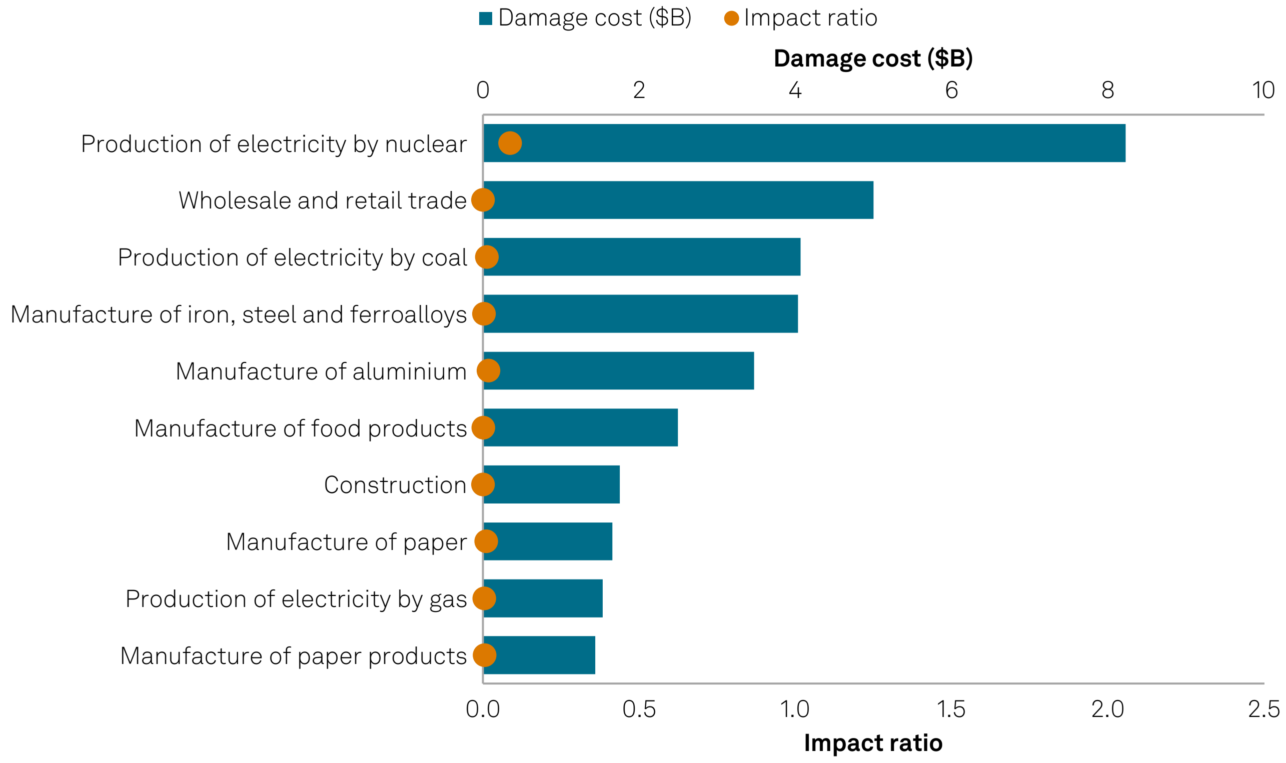
The water supply and sewerage utilities sector produces the highest environmental damage costs associated with pollutants released to water and land globally: $15.4 billion in environmental damage costs in 2021. This sector is responsible for treating, managing and transporting both drinking and wastewater, which leaves many points for its operations to result in water and land pollution.

For example, some US cities have systems that combine sewage and stormwater runoff in the same pipes.[23] These systems are prone to overflow during heavy rainstorms and will subsequently discharge untreated stormwater and waste into nearby waterbodies.[24] On a global scale, studies have found that more than 80% of untreated sewage is discharged into rivers and oceans, resulting in pollution as well as the spread of disease.[25]

The cultivation of oilseeds and cultivation of cereal grains are the second- and third-highest environmental damage cost sectors. As described later in this report (8.6.1, Crop cultivation), fertilizer and pesticide runoff during rainstorms or when snow melts can contaminate local streams, rivers and groundwater.

7.3.6 Waste

10 highest damage cost sectors for waste EKPI globally



EKPI = Environmental key performance indicator.
Source: S&P Global Sustainable1.

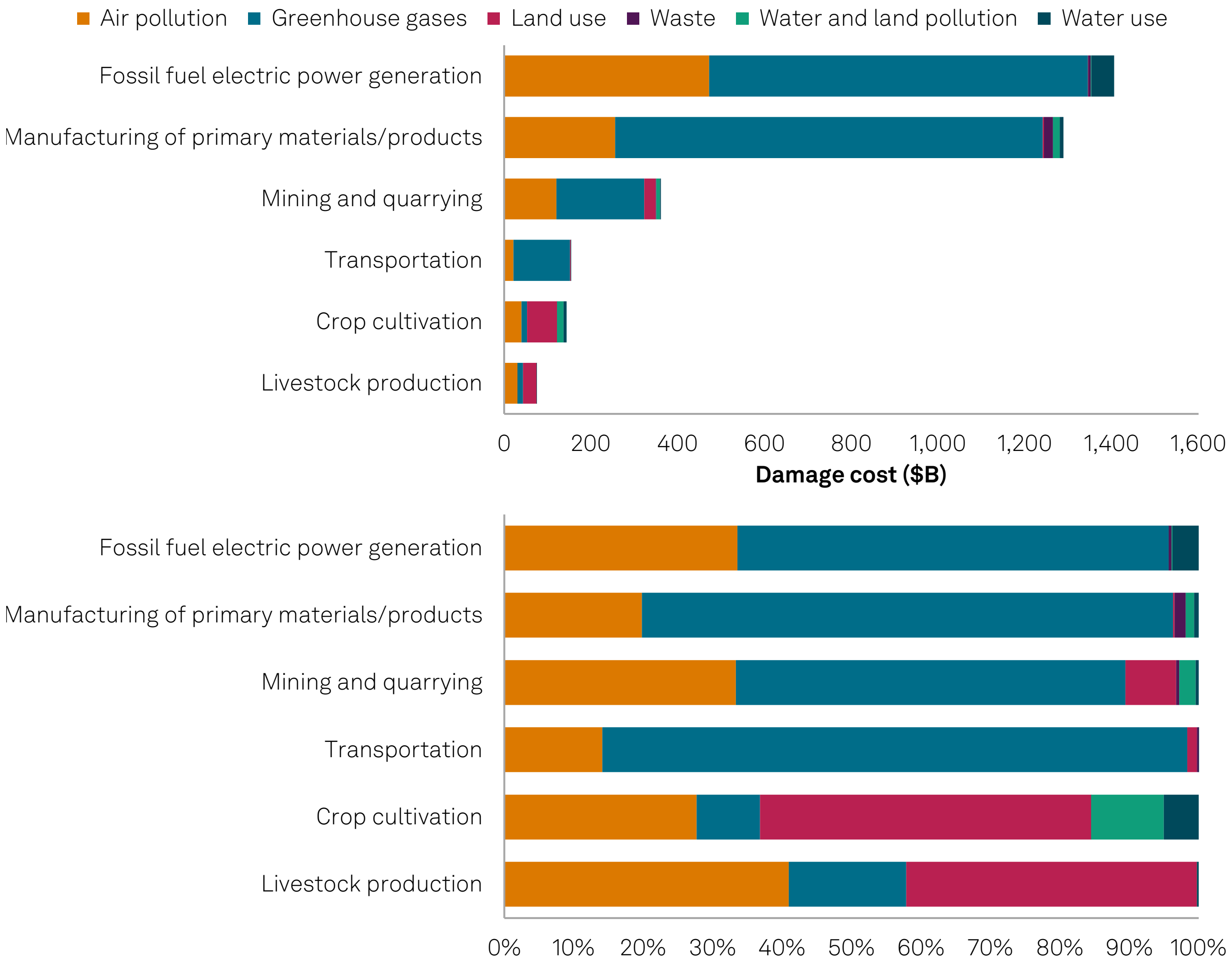
The sector with the highest environmental damage costs for waste is the production of electricity by nuclear, which produced $8.2 billion in environmental damage costs in 2021. Wholesale and retail trade was the second-highest environmental damage cost sector, followed by the production of electricity by coal.

Solid waste generation and disposal degrades the environment, indirectly impacting human wellbeing, and leading to external costs on society. Waste can include hazardous, non-hazardous and nuclear waste.

Nuclear waste in particular has posed a challenge for society, as most of it cannot be recycled and re-used to produce more nuclear power, according to the International Atomic Energy Agency (IAEA).[26] The IAEA in a 2022 report found that from 1954 to 2016, about 390,000 metric tons of spent fuel was discharged from nuclear plants, but only about one-third has been recycled, while the rest remains in storage.

8. Sector groups in depth

Top 6 sector groups by impact type



Source: S&P Global Sustainable1.

8.1 The top 6 sector groups

The six most significant sector groups of the 30 reviewed for this report were responsible for the vast majority of environmental damage costs: $3.43 trillion, or 92.4% of the total.

As with the aggregate and global sums, GHGs caused the highest environmental damage costs for most of the top six sector groups, representing 64.6% of the total. Air pollution accounted for 27.4% of the environmental damage costs, land use made up 3.8%, and water use represented 2.1% of the total. However, land use was the top driver of environmental damage costs for two sector groups: crop cultivation and livestock production.

Of all the sector groups reviewed in this report, electricity generated from fossil fuels, and coal in particular, had the highest environmental damage costs overall: about $1.41 trillion in 2021. GHGs and air pollution together account for 95.7% of the fossil fuel electric power generation sector group's impact.

The second ranking sector group involves the manufacturing of primary materials and products such as food and beverages, iron and steel, chemicals and plastics, and petroleum refining. Companies in this sector group caused $1.29 trillion in environmental damage costs in 2021, about 76.5% of which came from GHGs, followed by air pollution (19.8%).

The mining and quarrying sector group ranks third, estimated at $360.9 billion in environmental damage costs in 2021. The mining and quarrying sector group includes the extraction of crude petroleum and natural gas, coal and lignite, metal ores and minerals. Similar to the other top sector groups, GHGs are the most significant driver (56.1%), followed by air pollution (33.4%) and land use (7.3%).

The transportation sector group ranked fourth, estimated at $154.3 billion in 2021. Transportation includes the movement of cargo, passengers and materials via water, air, road and rail as well as pipelines. Cumulatively, GHGs and air pollution account for 98.3% of the environmental damage costs of the transportation sector group.

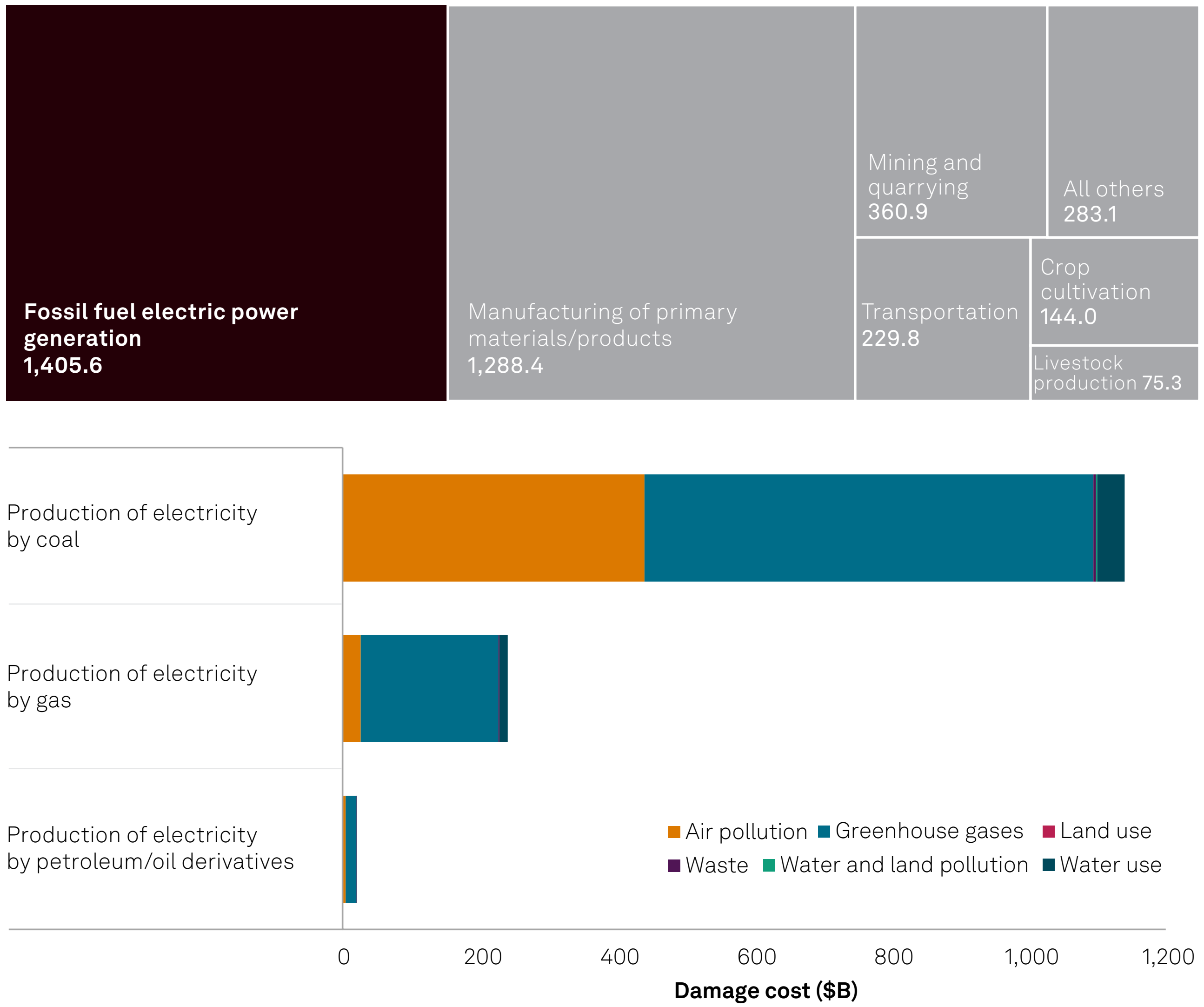
Crop cultivation and livestock production are the fifth- and sixth-highest sector groups, with total environmental damage costs in 2021 of $143.9 billion and $75.3 billion, respectively. Unlike the other top sector groups, land use was the most significant impact for crop cultivation and livestock production. Air pollution was the second highest EKPI for these sector groups.

Globally, agriculture generates some of the most significant harm to natural capital in terms of water and land use, air pollution and GHGs, and their resulting effects on ecosystems and ecosystem services. This analysis is limited to the direct operations of companies in the S&P Global BMI and does not fully capture the impact of agricultural activities globally — only those represented by the direct operations of these publicly traded companies.

Most of the six sector groups highlighted in this report are highly dependent on nature across their direct operations, and crop cultivation in particular has a very high dependency on ecosystem services.

8.2 Fossil fuel electric power generation

Impacts from fossil fuel sectors ($B)



Source: S&P Global Sustainable1.

Electricity generated from fossil fuels, and coal in particular, has the highest environmental damage costs of all the sector groups reviewed in this report: about $1.41 trillion in 2021. The fossil fuel power generation sector group includes three sectors: production of electricity by coal, production of electricity by gas, and production of electricity by petroleum or oil derivatives.

For the fossil fuel electric power generation sector group in the S&P Global BMI, GHGs account for the majority of the overall environmental damage costs (62.1%), followed by air pollution (33.6%), and water use (3.8%). Together, the GHG and air pollution impacts account for 95.7% of the sector group's environmental damage costs.

On a regional level, nearly half of the costs (48.8%) from the fossil fuel electric power generation sector occur in Eastern Asia, with Southern Asia comprising 21% of the total, followed by 12.4% in Northern America.

The production of electricity by coal sector's impacts follows a similar trend to the broader group, with environmental damage costs highest in Eastern Asia and Southern Asia, followed by Northern America, Southeastern Asia and Eastern Europe. The top damages from gas-fired generation are in Northern America.

Most of the 10 highest environmental damage cost fossil fuel sector-regions have high impact ratios, particularly coal-fired generation. Environmental damage costs from the production of electricity by coal across several Asian regions, Northern America and Eastern Europe all exceed the revenue generated by the sector in those geographies. In Southern Asia, the environmental damage costs were 11 times greater than revenue – the highest impact ratio of any sector in any region.

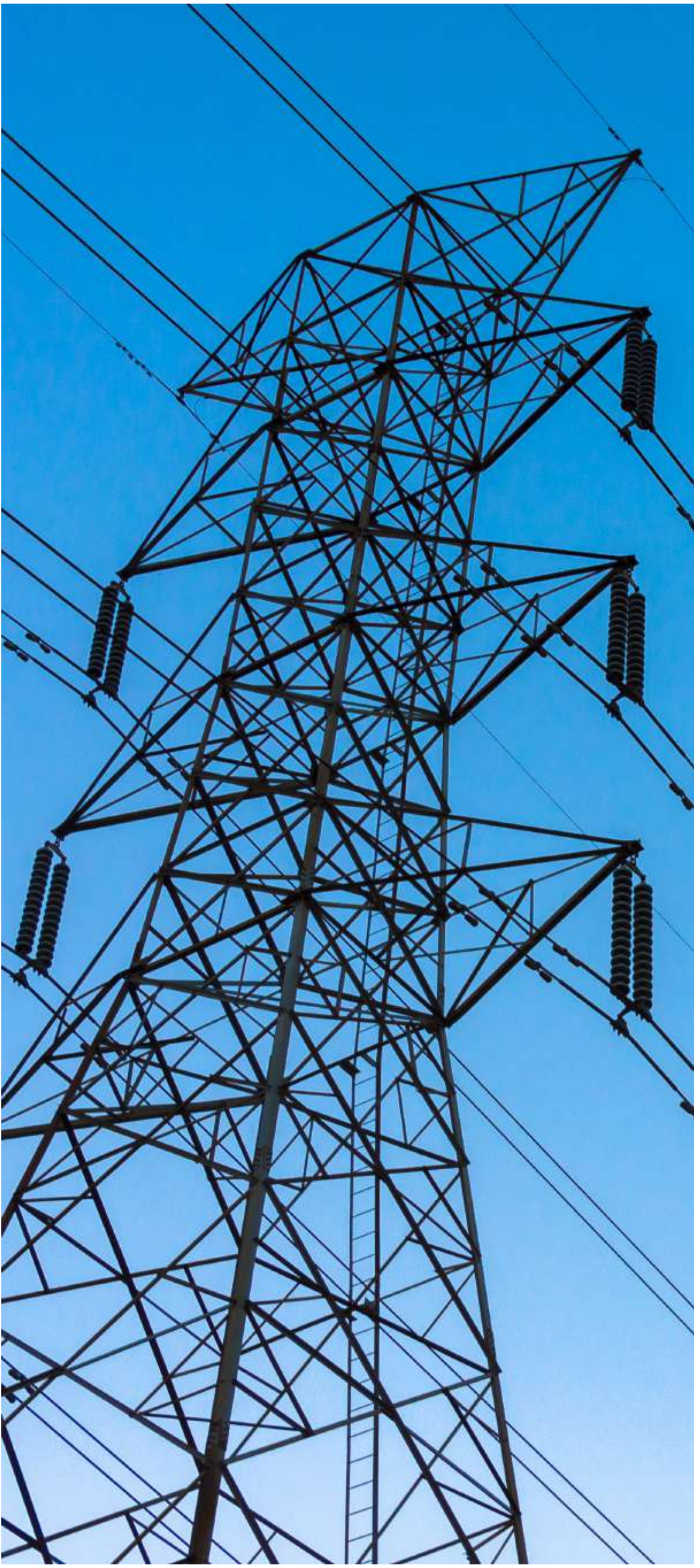
Why coal-fired generation is so costly

The production of electricity by coal generates high costs for nature and society for multiple reasons. It has the highest environmental damage costs across all EKPIs considered, but most importantly GHGs and air pollution.

Coal has a higher carbon footprint than natural gas. The CO_2 environmental damage costs from coal-fired generation in this study were found to be more than three times higher than from gas-fired generation. Coal-fired generation also produces high levels of air pollutants including sulfur oxides (SOx), particulate matter (PM) and nitrogen oxides (NOx) through the coal combustion process. These pollutants harm human health, notably provoking respiratory illnesses following inhalation.[27]

However, steps can be taken to remove impurities from coal or to remove sulfur from smoke before it leaves the power plant's smokestack. And a number of countries and regions around the world have regulations limiting SOx, PM and NOx pollutants from coal-fired generation, including the US, EU, Japan, China, Australia and other Southeast Asian countries.[28 29]

Compared to gas-fired generation, this analysis found SOx environmental damage costs from coal-fired generation to be over 6,000 times SOx damages from gas-fired generation.



Fossil fuel generation and nature risk

The fossil fuel electric power generation sector group is highly dependent on nature, particularly on several water-related ecosystem services: ground water, surface water and water flow maintenance, which refers to the hydrological cycle that recharges aquifers and maintains surface water flows. Natural gas and coal-fired power plants rely on water to operate, and they also have the highest water use impact environmental damage costs across all sectors reviewed.

This demonstrates that a sector's environmental damage costs often directly affect an element of natural capital that every sector depends on. Reducing the water use of the fossil fuel power generation sector group would also contribute to lessening its dependency on water-based ecosystem services.

A review of relevant assets within the fossil fuel electric power generation sector group of the S&P Global BMI shows that 13% of these assets overlap with KBAs. The facility types included in this analysis are company headquarters, energy infrastructure, institution address, power generation and power plant.

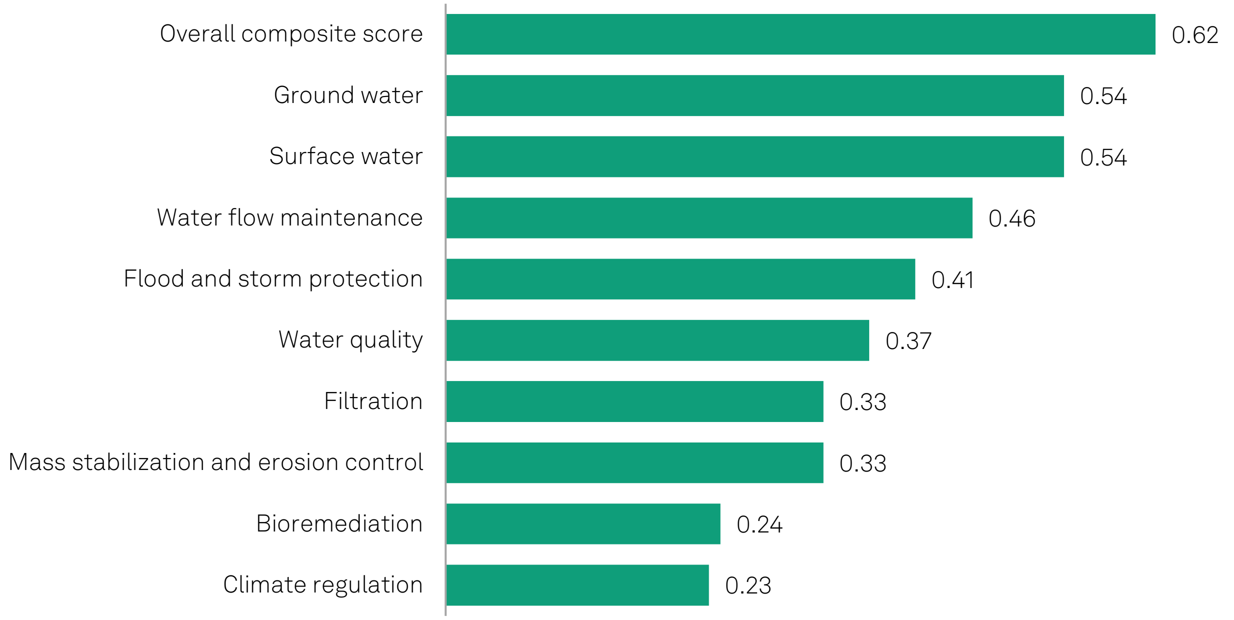
10 highest damage cost fossil fuel sector-regions

Sector	Region	Damage cost ($B)	Impact ratio
Production of electricity by coal	Eastern Asia	628.71	3.9
Production of electricity by coal	Southern Asia	289.04	11.0
Production of electricity by coal	Northern America	99.61	2.3
Production of electricity by gas	Northern America	71.87	1.0
Production of electricity by gas	Eastern Asia	53.08	0.9
Production of electricity by coal	Southeastern Asia	43.40	2.1
Production of electricity by coal	Eastern Europe	30.82	2.4
Production of electricity by gas	Middle East	28.70	1.3
Production of electricity by gas	Southeastern Asia	20.24	1.0
Production of electricity by gas	Western Europe	15.48	0.4

Source: S&P Global Sustainable1.

Fossil fuel electric power generation is most dependent on water-related ecosystem services

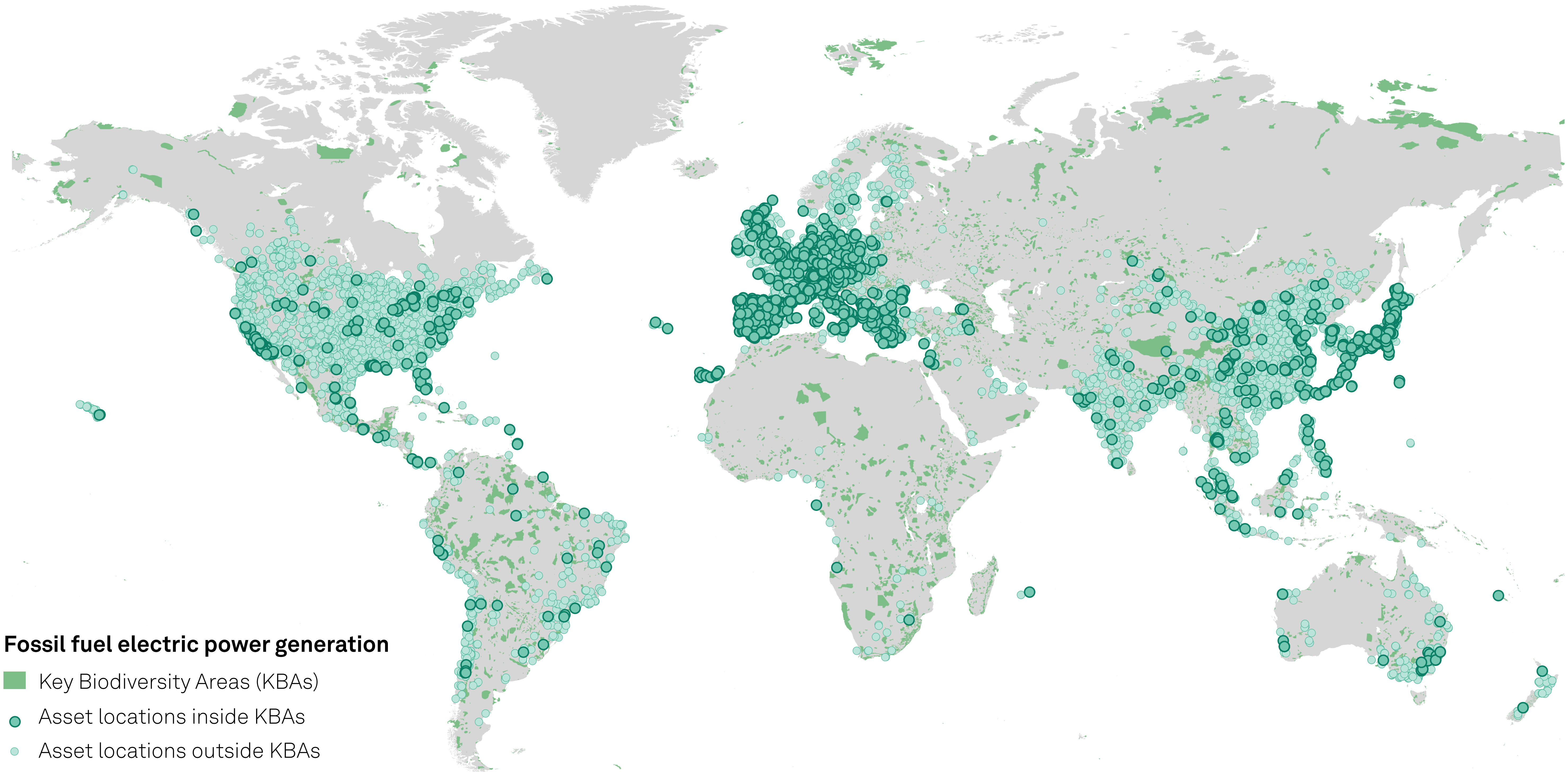
Nature dependency risk scores for the fossil fuel electric power generation sector group of the S&P Global BMI



Ecosystem services with a dependency score of 0 are omitted for clarity: animal-based energy, buffering and attenuation of mass flows, dilution by atmosphere and ecosystems, disease control, fibers and other materials, genetic materials, maintain nursery habitats, mediation of sensory impacts, pest control, pollination, soil quality, and ventilation.
Ecosystem service definitions can be found at https://www.spglobal.com/esg/solutions/nature-risk-profile-methodology.pdf.
Source: S&P Global Sustainable1.

Sector groups in depth

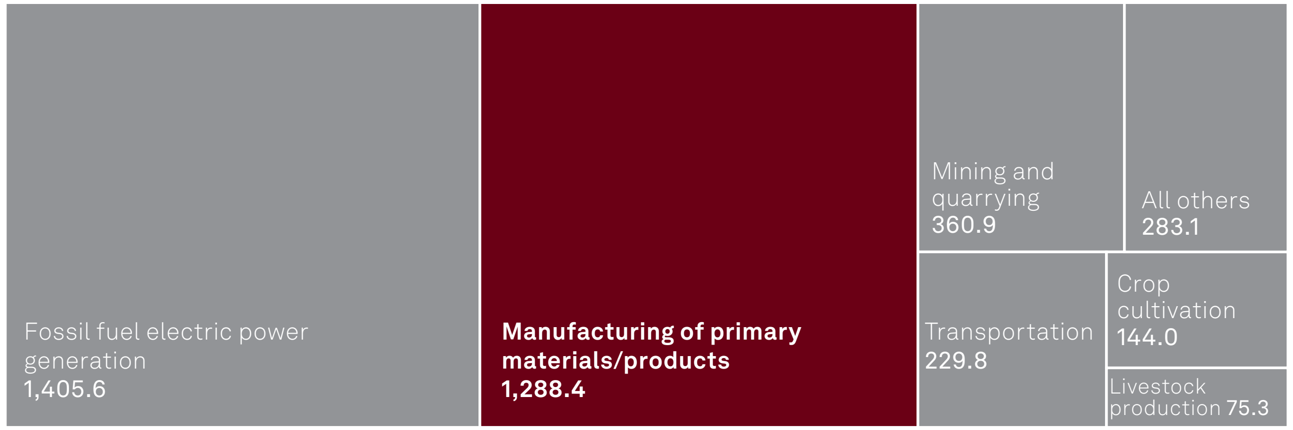
Fossil fuel power generation assets in the S&P Global BMI overlapping with Key Biodiversity Areas

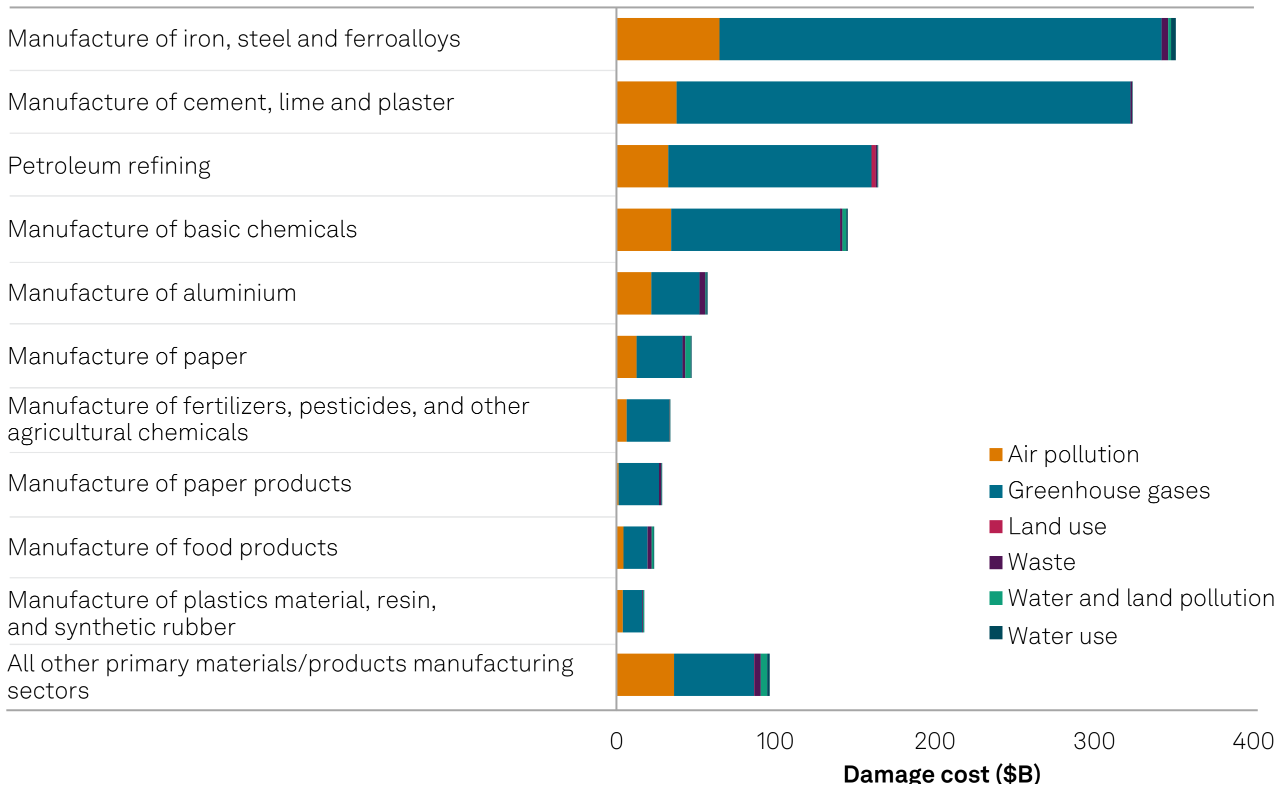


Select facility types displayed for illustrative purposes: company headquarters, energy infrastructure, institution address, power generation, power plant.
Map credit: Jonathan Paul Lalgee.
Source: S&P Global Sustainable1.

8.3 Manufacturing of primary materials and products

Impacts from manufacturing sectors ($B)





Source: S&P Global Sustainable1.

The second-highest sector group in the S&P Global BMI by environmental damage cost is the manufacturing of primary materials and products, which caused about $1.29 trillion in environmental damage costs in 2021.

Within this sector group are 35 sectors including petroleum refining; manufacture of food product and beverages; manufacture of pharmaceuticals and medicines; manufacture of iron, steel and ferroalloys; manufacture of chemicals; manufacture of plastics material, resin, and synthetic rubber; and the manufacture of cement, lime and plaster.

Eastern Asia produces the largest share (48.7%) of total environmental damage costs from the manufacturing of primary materials and products sector group, with the second-highest region, Northern America, contributing 13.6% of the costs.

Eastern Asia and Southern Asia generate the largest environmental damage costs from the manufacture of cement, lime and plaster and the manufacture of iron, steel, and ferroalloy, while petroleum refining impacts were the greatest in Northern America, Eastern Asia, Southern Asia and the Middle East.

Three of the 10 highest environmental damage cost primary materials manufacturing sector-regions have high impact ratios. Specifically, environmental damage costs from the manufacture of cement, lime and plaster in Southern Asia, Eastern Asia and Northern America all have an impact ratio greater than 1.0, meaning that the unpriced natural capital costs the sector generates are greater than the sector's revenue in those regions.

Why GHGs and pollution from primary materials manufacturing are so costly

Cumulatively, GHGs and air pollution account for over 95% of the environmental damage costs for the manufacturing of primary materials and products sector group. Broken down into impacts, GHGs make up the majority (76.5%), followed by air pollution (19.8%) and waste (1.6%). Water and land pollution each constitute around 1% of the sector group's remaining environmental damage costs.

Sectors within the manufacturing of primary materials and products with the highest environmental damage costs are the manufacture of iron, steel and ferroalloys (27.2%); the manufacture of cement, lime and plaster (25.1%); and petroleum refining (12.8%).

Emissions from the production of cement, iron, steel and chemicals are seen as particularly difficult to abate because the production process requires fossil fuels and/or very high temperatures, which result in high levels of industrial carbon emissions. Technologies such as low-carbon hydrogen or carbon capture and sequestration can help reduce emissions for these processes but would need to be ramped up significantly above current levels to achieve a net zero emissions scenario, according to the International Energy Agency (IEA).[30 31]

Primary materials manufacturing and nature risk

The primary materials and products manufacturing sector group is highly dependent on ecosystem services such as mass stabilization and erosion control, bio-remediation, and flood and storm protection.

Examples of mass stabilization and erosion control include when vegetation on slopes prevents avalanches and landslides or when mangroves, sea grass and macro-algae provide erosion protection for coasts.

Bio-remediation occurs when living organisms such as micro-organisms, plants, algae and some animals degrade, reduce and/or detoxify contaminants from soil and water. The living organisms typically do this by metabolizing the contaminant and converting it into a less toxic form, such as CO_2 or water.

A review of relevant assets within the primary materials manufacturing sector group of the S&P Global BMI shows that 6% of these assets overlap with KBAs. The facility types included in this analysis are biofuel sites, cement plants, manufacturing facilities, refinery and chemical plants and steel plants.

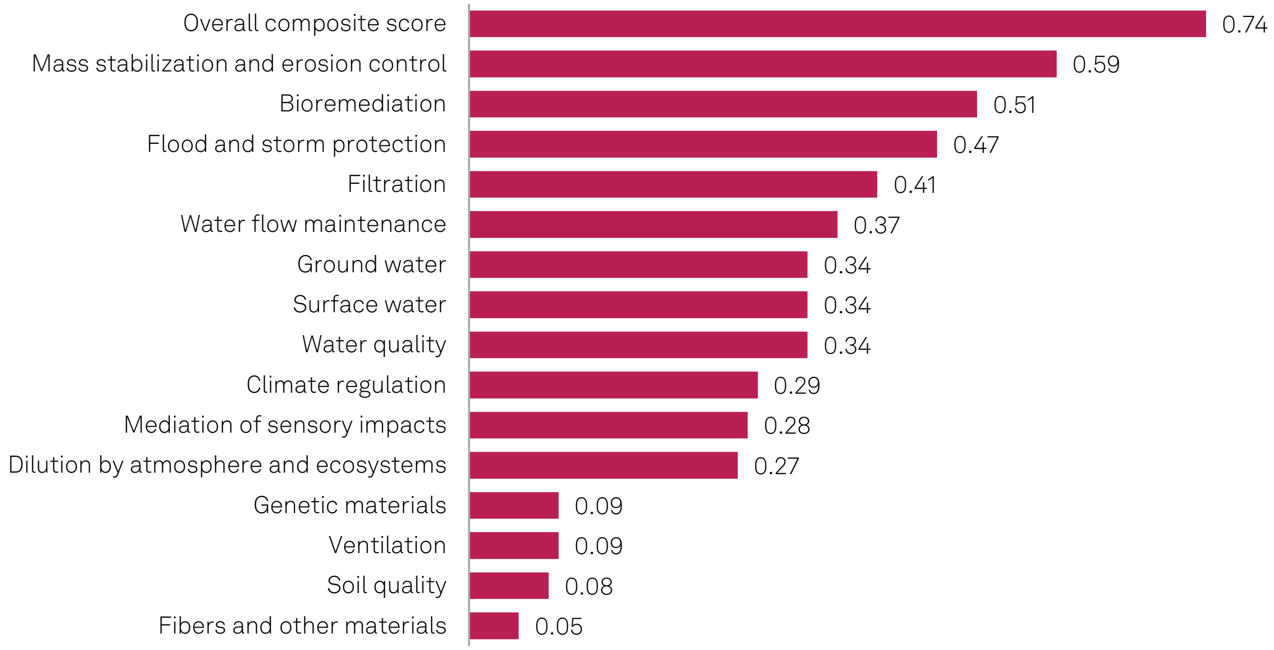
10 highest damage cost manufacturing sector-regions

Sector	Region	Damage cost ($B)	Impact ratio
Manufacture of iron, steel and ferroalloys	Eastern Asia	200.85	0.4
Manufacture of cement, lime and plaster	Eastern Asia	182.65	1.3
Manufacture of basic chemicals	Eastern Asia	76.89	0.2
Manufacture of cement, lime and plaster	Southern Asia	45.63	1.6
Manufacture of iron, steel and ferroalloys	Southern Asia	44.66	0.8
Petroleum refining	Northern America	40.17	0.1
Manufacture of iron, steel and ferroalloys	Northern America	34.78	0.2
Petroleum refining	Eastern Asia	32.45	0.1
Manufacture of aluminium	Eastern Asia	29.88	0.3
Manufacture of cement, lime and plaster	Northern America	26.08	1.0

Source: S&P Global Sustainable1.

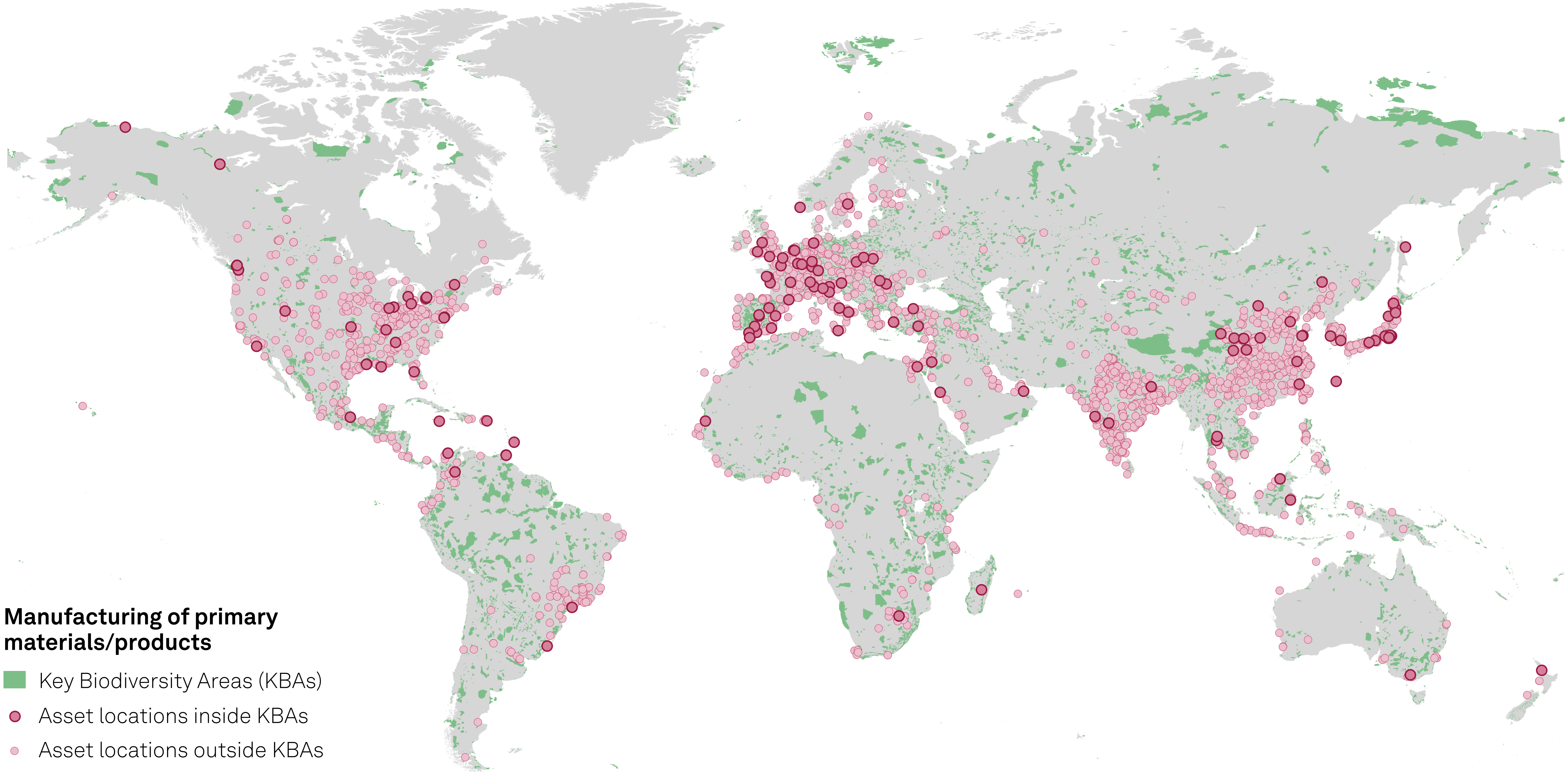
Primary materials and products manufacturing is most dependent on erosion control

Nature dependency risk scores for the manufacturing of primary materials and products sector group of the S&P Global BMI



Ecosystem services with a dependency score of 0 are omitted for clarity: animal-based energy, buffering and attenuation of mass flows, disease control, maintain nursery habitats, pest control, and pollination.
Ecosystem service definitions can be found at https://www.spglobal.com/esg/solutions/nature-risk-profile-methodology.pdf.
Source: S&P Global Sustainable1.

Primary materials and products manufacturing assets in the S&P Global BMI overlapping with Key Biodiversity Areas



Select facility types displayed for illustrative purposes: biofuel, cement plant, manufacturing, refinery and chemicals plant, steel plant.
Map credit: Jonathan Paul Lalgee.
Source: S&P Global Sustainable1.

Human rights in manufacturing operations and supply chains

For the manufacturing of primary materials and products sector group, addressing natural capital risk is just part of the picture. Companies are also coming under pressure from investors and consumers to have strong governance practices on social issues such as human rights, both in direct operations and supply chains. For example, the Investor Alliance for Human Rights was launched in 2018 and currently includes more than 200 institutional investors with over $12 trillion in assets under management.[32]

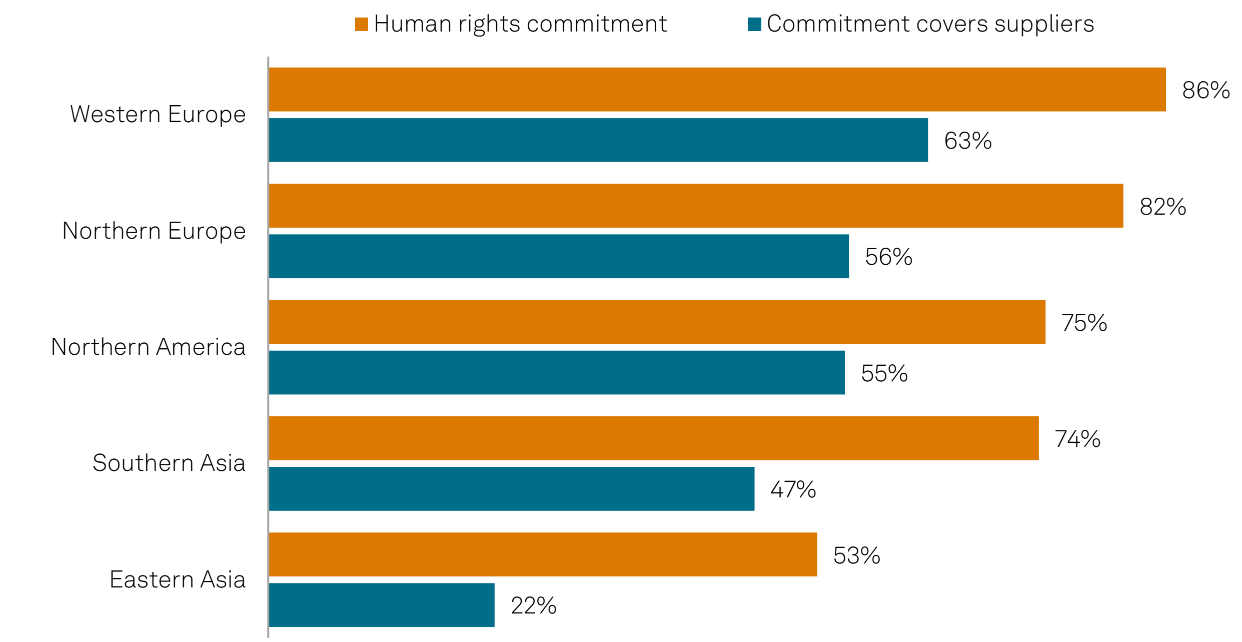
Human rights issues for manufacturing companies can vary depending on the location and what processes, equipment and materials are used, according to the UN Environment Programme Finance Initiative (UNEPFI) Human Rights Guidance tool for the financial sector, which includes a review of the biggest human rights challenges for general manufacturing.[33] But in general, UNEPFI indicates that key risks include child labor, workplace conditions, ethical sourcing of materials, and awareness of how the environmental impact of manufacturing processes can affect the health and livelihood of employees and communities.

The 2022 S&P Global Corporate Sustainability Assessment (CSA) shows that 57% of companies across all sectors in the S&P Global BMI have a publicly available, company-specific policy in place for their commitment to respect human rights. As for companies in the S&P Global BMI that generate at least 50% of their revenue from manufacturing, 64% have a human rights policy. On a regional scale, 86% of manufacturing companies in Western Europe and 82% in Northern Europe had human rights policies, followed by companies in Northern America (75%). The rate of commitment for companies in Southern Asia and Eastern Asia was 74% and 53%, respectively.

However, a significantly smaller share of companies have human rights commitments that extend to their supply chains, where the potential for human rights issues can be much greater. The share of companies in Western and Northern Europe with commitments that extend to suppliers is more than 20 percentage points lower than the share with a general commitment.

Human rights commitments are common among manufacturers, but supply chains are not always covered

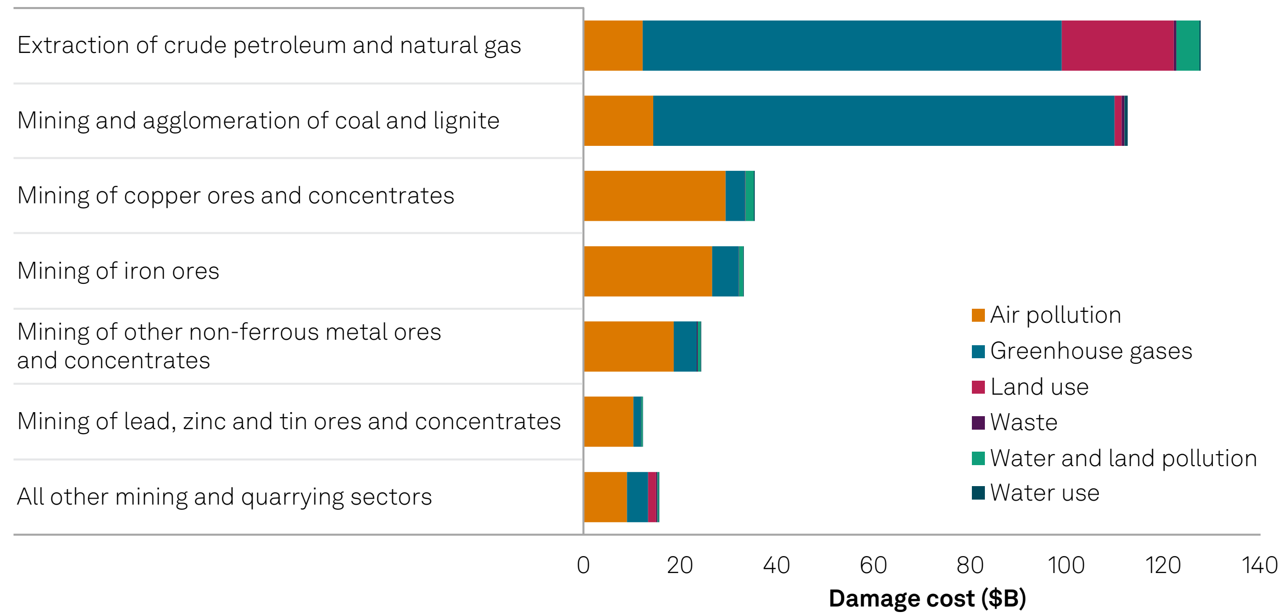
Percentage of assessed S&P Global BMI manufacturing companies with a publicly available commitment to human rights



Results based on responses from 3,324 companies in the S&P Global BMI index assessed in the 2022 S&P Global Corporate Sustainability Assessment. Companies with at least 50% revenue share from manufacturing activities were included.
Chart includes regions with a sample size of at least 150 companies.
Source: S&P Global Sustainable1.

8.4 Mining and quarrying

Impacts from mining and quarrying sectors ($B)



Source: S&P Global Sustainable1.

The third-most significant sector group in the S&P Global BMI is mining and quarrying, which generated $360.9 billion in environmental damage costs in 2021. GHGs are the most significant driver of those costs (56.1%), followed by air pollution (33.4%). Land use environmental damage costs accounted for 7.3% of the total.

The mining and quarrying sector group includes the extraction of crude petroleum and natural gas, mining and agglomeration of coal and lignite, mining of metal ores and concentrates and mining of non-metallic minerals, as well as the specialized support services for mining.

While much of the emissions associated with fossil fuels occurs at the customer level when they are combusted, oil and gas extraction companies in 2022 were responsible for 40% of global methane emissions, largely through venting, flaring (burning the methane at the extraction site) or from equipment leaks.[34] Methane is 25 times more potent[35] of a GHG than CO_2, but methane does not stay in the atmosphere for as long — about 25 years versus centuries for CO_2.[36]

About 46.6% of the sector group's environmental damage costs occur in Eastern Asia, which is significantly higher than the second-highest region, Northern America (16.3%).

The largest environmental damage costs from the extraction of crude petroleum and natural gas occur in Northern America, followed by the Middle East and Eastern Asia. The biggest impacts for this sector globally are GHGs and land use. For mining and agglomeration of coal and lignite, which had the second-highest environmental damage costs of the sectors within the group, Eastern Asia and Southern Asia are the top regions for environmental damage costs.

Of the 10 highest environmental damage cost mining and quarrying sector-regions, the mining of iron ores in Southern Asia had an impact ratio greater than 1.0, meaning that the unpriced natural capital cost of that sector is greater than the revenue it generates in that region.

How mining and quarrying can impact nature and human health

Mineral mining and the extraction of crude petroleum and natural gas can degrade natural habitats[37] and harm biodiversity both at the mining and extraction site and through road and railway development in nearby areas.[38] These activities can also impact the health, quality of life, and general well-being of people living in nearby communities.[39]

One example is the process of hydraulic fracturing (fracking) for extracting oil and natural gas, which can impact local ecosystems as well as the drinking water supplies of nearby communities. Fracking involves injecting water, sand and chemicals into a well to break up underground bedrock to extract oil and gas.[40]

Fracking has been tied to increased seismic activity near the injection site, and the resulting wastewater — if not managed properly — can degrade surface water quality, contaminate groundwater and be harmful to wildlife.[41] The US Environmental Protection Agency has found that fracking can negatively impact drinking water quality.[42] Moreover, a study published in the Journal of Health Economics in 2022 found a link between water pollution from fracking and impacts to infant health.[43]

Research on the environmental public health impacts of upstream oil extraction has found increased risk of cancer, autoimmune disorders, allergies, respiratory symptoms and other health issues.[44] Onshore oil and gas extraction, partly through land use and habitat fragmentation, can have extensive impacts on ecosystem services.[45]

Meanwhile, demand for new supplies of minerals such as cobalt, lithium and copper, is expected to grow due to the low-carbon transition, which will require a significant build out and deployment of renewables, electric vehicles and other clean energy technologies. For example, S&P Global Commodity Insights forecasts that sales of electric vehicles globally will double from 2023 to 2027 and that supply challenges for some of the metals needed for electric vehicle batteries, with shortages of cobalt and lithium expected through 2027..[46]

This growing demand for energy transition-related minerals and metals is prompting an increase in mining exploration around the world, including in some of the world's most important areas for biodiversity. Research in 2022 by S&P Global Sustainable1 found more than 1,200 mining sites that intersect with KBAs, and 29% of those sites are for extracting minerals needed for the low-carbon energy transition.[47]

Mining and nature risk

The mining and quarrying sector group is highly dependent on ecosystem services, namely climate regulation, mass stabilization and erosion control, ground water and surface water.

Climate regulation refers to the ecosystem service nature provides to regulate or modulate the climate on a global, regional and local and micro-scale. Globally, climate regulation can help lower global emissions by acting as a carbon sink to absorb and store carbon emissions from the atmosphere in soils, vegetable biomass and oceans. On a regional level, the climate is regulated by ocean currents and winds. And at local and micro-levels, vegetation can modify temperatures, humidity and wind speeds.

The excavation and extraction of minerals and metals can affect soil and water quality and can result in erosion-prone landscapes, which helps explain why this sector group depends on many of the ecosystem services associated with stabilizing the soil and restoring water quality.

A review of relevant assets within the mining and quarrying sector group of the S&P Global BMI shows that 6% of assets overlap with KBAs. The facility types included in this analysis are coal mine, company headquarters and mining property.

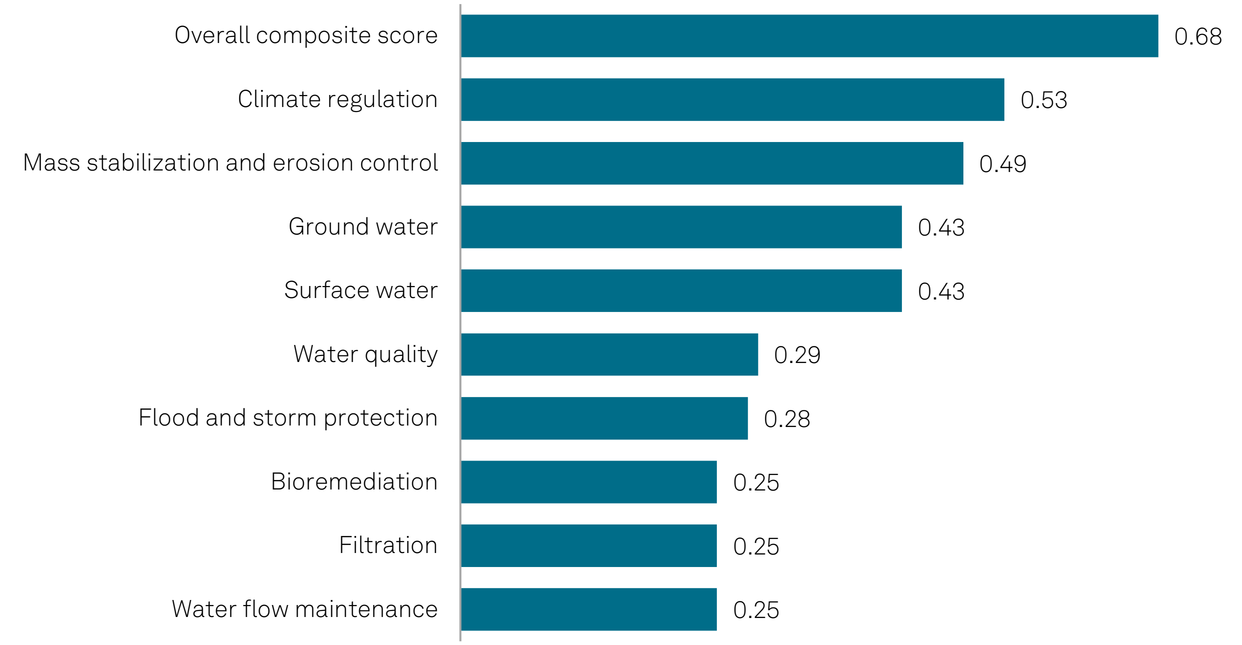
10 highest damage cost mining and quarying sector-regions

Sector	Region	Damage cost ($B)	Impact ratio
Mining and agglomeration of coal and lignite	Eastern Asia	84	0.5
Extraction of crude petroleum and natural gas	Northern America	47	0.1
Extraction of crude petroleum and natural gas	Middle East	25	0.1
Extraction of crude petroleum and natural gas	Eastern Asia	22	0.2
Mining of copper ores and concentrates	Eastern Asia	21	0.3
Mining of iron ores	Eastern Asia	18	0.1
Mining of other non-ferrous metal ores and concentrates	Eastern Asia	14	0.2
Mining and agglomeration of coal and lignite	Southern Asia	10	0.6
Mining of iron ores	Southern Asia	9	1.1
Extraction of crude petroleum and natural gas	Southern Asia	8	0.2

Source: S&P Global Sustainable1.

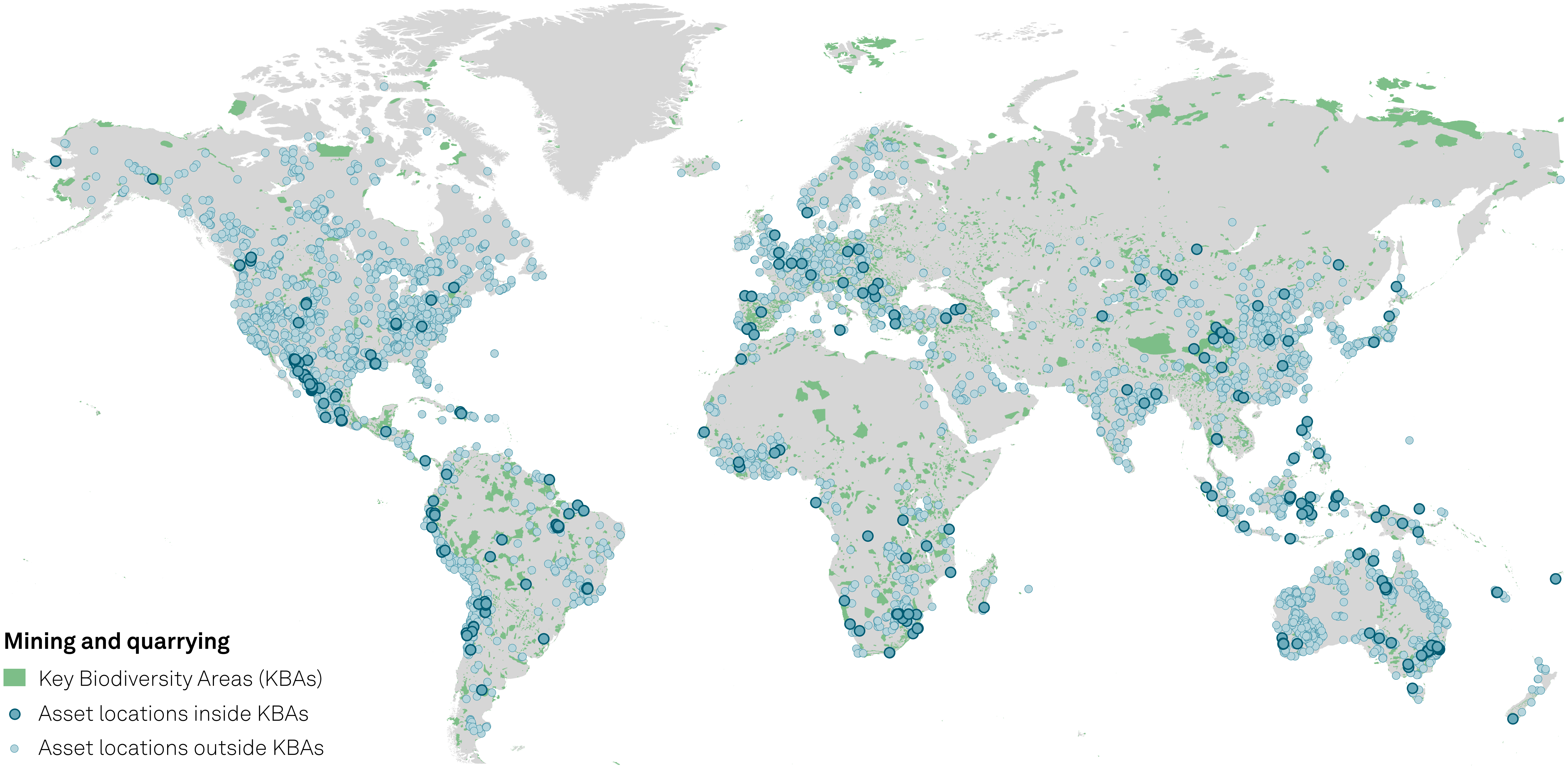
Mining and quarrying has a high level of dependency on ecosystem services

Nature dependency risk scores for the mining and quarrying sector group of the S&P Global BMI



Ecosystem services with a dependency score of 0 are omitted for clarity: animal-based energy, buffering and attenuation of mass flows, dilution by atmosphere and ecosystems, disease control, fibers and other materials, genetic materials, maintain nursery habitats, mediation of sensory impacts, pest control, pollination, soil quality, and ventilation.
Ecosystem service definitions can be found at https://www.spglobal.com/esg/solutions/nature-risk-profile-methodology.pdf.
Source: S&P Global Sustainable1.

Mining and quarrying assets in the S&P Global BMI overlapping with Key Biodiversity Areas



Select facility types displayed for illustrative purposes: coal mine, company headquarters, mining property.
Map credit: Jonathan Paul Lalgee.
Source: S&P Global Sustainable1.

Engaging with local communities and Indigenous peoples

Oil and gas extraction as well as mining companies often face disputes over land use issues, especially concerns from local communities[48] and Indigenous peoples[49] who face the risk of projects affecting their health, property values and local ecosystems.[50] Land use represents 7.3% of the natural capital costs for this sector group, a substantially higher share than for the fossil fuel power generation and primary material manufacturing sector groups.

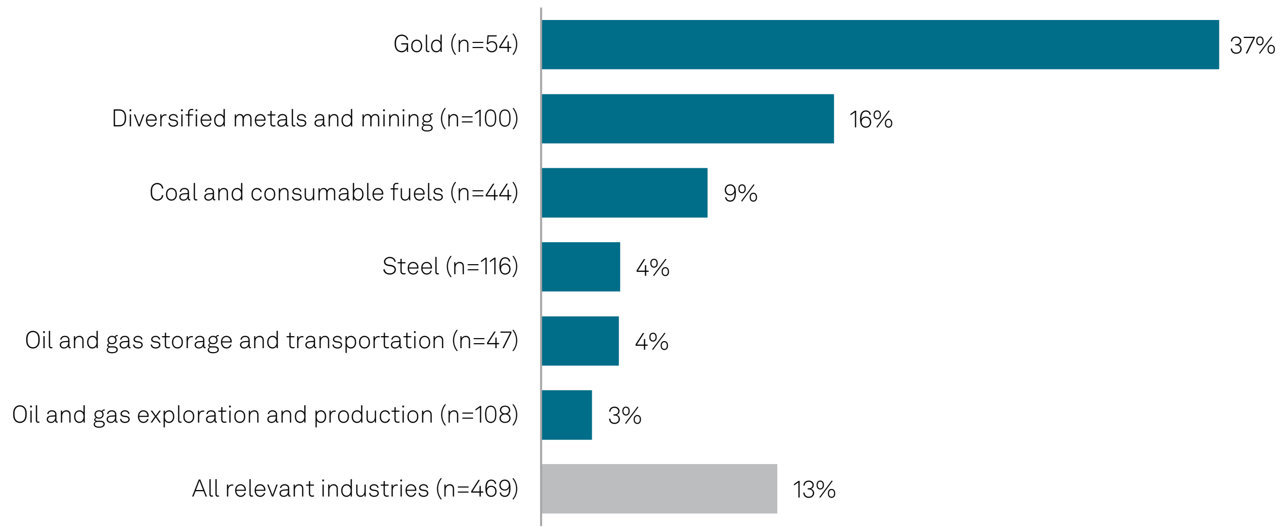
Land acquisition can have adverse impacts on communities and the people using the land, resulting in potential long-term hardship and impoverishment of those affected, as well as environmental damage. How companies deal with issues of responsible land acquisition, fair relocation assistance and mine site closure is key in protecting affected communities and the environment.

The 2022 S&P Global Corporate Sustainability Assessment (CSA) shows corporate practices to manage these issues are not widespread among mining companies in the S&P Global BMI. Only 13% of companies have a general corporate approach to working with project-affected communities on topics related to physical and economic resettlement, with wide differences between industries.

Corporate performance is stronger on the CSA topic related to engagement with Indigenous peoples, but these policies still appear to be the exception rather than the rule for relevant industries. About 30% of companies in relevant industries engage with Indigenous communities affected by their business operations. The gold mining industry was the only one where a majority of companies actively engage with affected Indigenous communities in some way, while the rate was 32% for diversified metals mining firms and for oil and gas exploration and production companies.

Only 13% of companies in relevant industries have a corporate approach to community resettlement

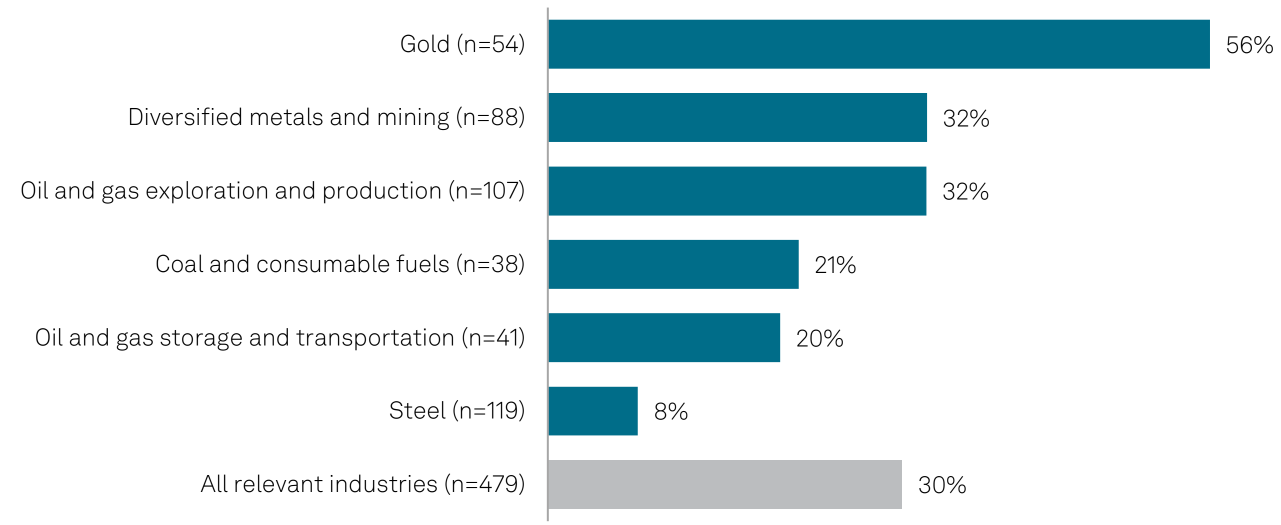
Percentage of assessed S&P Global BMI companies with a corporate approach to physical and economic resettlement for communities affected by projects



Results based on responses from 469 companies in the S&P Global BMI index assessed in the 2022 S&P Global Corporate Sustainability Assessment (CSA). Chart includes relevant GICS sub-industries with a sample size of at least 25 companies.
Source: S&P Global Sustainable1.

About 30% of companies in relevant industries engage with indigenous communities

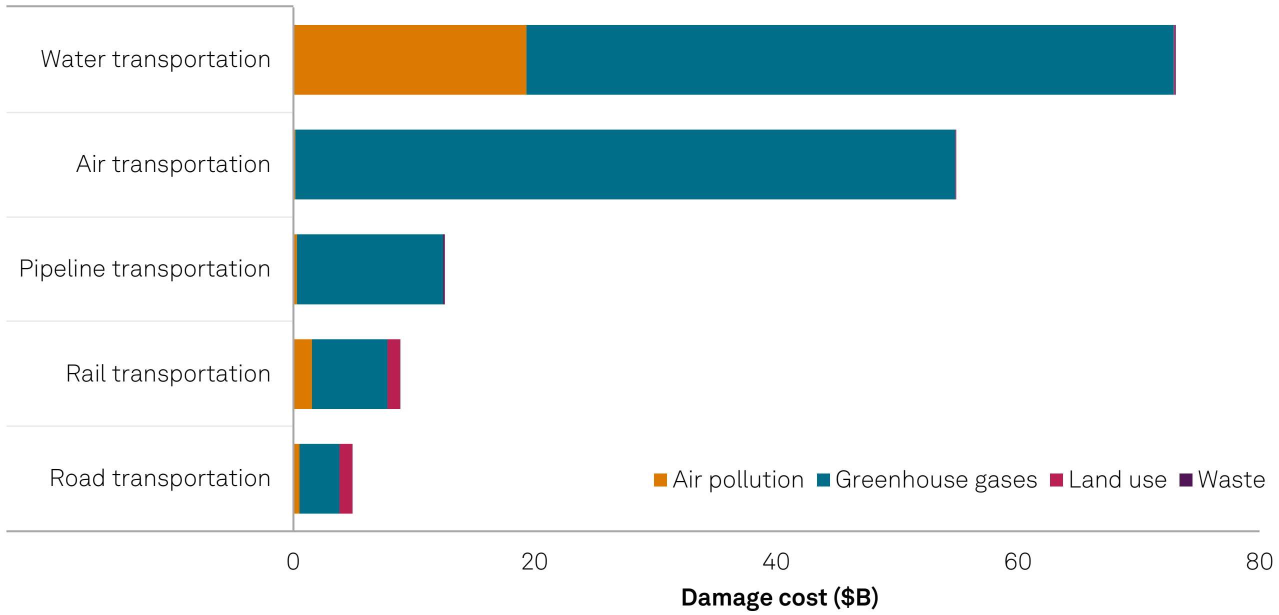
Percentage of assessed S&P Global BMI companies engaging with indigenous communities by industry



Results based on responses from 479 companies in the S&P Global BMI index assessed in the 2022 S&P Global Corporate Sustainability Assessment (CSA). Chart includes relevant GICS sub-industries with a sample size of at least 25 companies.
Source: S&P Global Sustainable1.

8.5 Transportation

Impacts from transportation sectors ($B)



Source: S&P Global Sustainable1.

The transportation sector group ranked fourth for overall environmental damage costs, estimated at $154.3 billion in 2021.

Transportation includes the movement of cargo, passengers and materials via water, air, road and rail, as well as pipelines. For this sector group, GHGs account for most of the costs (84.2%), followed by air pollution (14.1%), with land use making up 1.4%.

Water and air transportation account for the vast majority of environmental damage costs in the sector group. The main causes of GHGs and air pollution in water and air transportation are the combustion of fossil fuels, such as diesel and jet fuel, by ships and aircraft, as well as the release of pollutants from exhaust emissions. In terms of GHGs, the air transportation sector has a slightly higher impact compared to water transportation.

When it comes to air pollution, however, water transportation generates larger environmental damage costs than other transportation sectors. Cargo ships and other water transportation vessels typically use lower-grade fuel oil known as bunker fuel, and there is only limited implementation of emission control measures in the shipping sector.[51] As a result, water transportation releases a greater quantity of by-products, including sulfur oxides (SOx) and nitrogen oxides (NOx) into the atmosphere compared to air transportation, where higher-grade fuels and more stringent emission control practices are standard. These pollutants, also produced by coal-fired power generation, harm human health, notably provoking respiratory illnesses following inhalation.

However, the water transport sector, and especially maritime shipping, is taking steps to reduce its carbon footprint. The maritime shipping industry has several low-carbon fuel alternatives in the early stages of development and deployment.[52] Also, the International Maritime Organization, which regulates the maritime industry, in July 2023 adopted a low-carbon strategy that includes the eventual goal of reaching net-zero emissions from international shipping “close to” 2050.[53]

Ground transportation decarbonization options include electrifying vehicles, which carries its own infrastructure and public adoption challenges. But while batteries are the key to decarbonizing ground transportation, they are too heavy for long-haul flights, and so aviation companies are looking to integrate more sustainable aviation fuels (SAFs) into their supplies. However, the industry is still in the early stages of adoption. SAFs accounted for only 0.2% of total jet fuel used globally in 2023.[54]

Regional environmental damage costs from transportation are highest in Eastern Asia, Northern America and Western Europe. Within that sector group, the bulk of environmental damage costs for water transportation and air transportation occur in Eastern Asia and Northern America. When assessing the impact of air pollutant emissions from the water and air transportation sectors, we have adjusted for emissions that occur far out at sea, or at high altitudes, distant from densely populated areas, and therefore resulting in less harm to human health.

However, relatively high-water transportation environmental damage costs in Asia are driven by the sector’s air pollution impact and the population density of the region. Many Asian countries contain multiple coastlines, archipelagos and rivers, allowing water transportation, such as ferries, river transport and coastal shipping, to provide a relatively efficient means of moving people and goods in densely populated urban areas, to support economic growth. However, it also exposes residents to the particularly harmful air pollution generated by low-grade fuels.

Unlike other top sector groups, none of the 10 highest environmental damage cost transportation sector-regions have an impact ratio greater than 1.0, meaning that their environmental damage costs do not outweigh their revenues. The highest environmental damage cost impact ratio for the transportation sector-regions is 0.4, for water transportation in Southern Asia.

10 highest damage cost transportation sector-regions

Sector	Region	Damage cost ($B)	Impact ratio
Water transportation	Eastern Asia	26.9	0.2
Air transportation	Northern America	21.9	0.2
Air transportation	Eastern Asia	14.4	0.2
Water transportation	Northern America	13.9	0.2
Water transportation	Western Europe	7.1	0.2
Pipeline transportation	Northern America	6.0	0.0
Rail transportation	Northern America	5.3	0.1
Water transportation	Southern Asia	4.9	0.4
Water transportation	Northern Europe	4.2	0.2
Air transportation	Western Europe	4.1	0.2

Source: S&P Global Sustainable1.

Transportation and nature risk

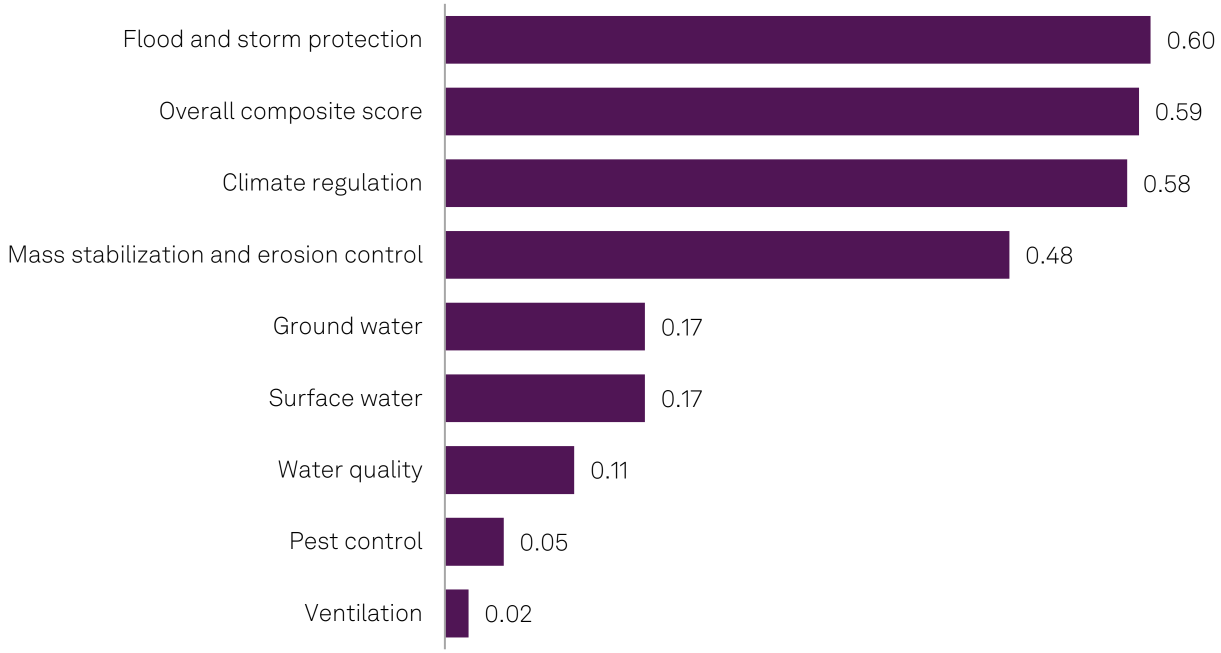
The transportation sector group is moderately dependent on nature's ecosystem services, particularly flood and storm protection, climate regulation, and mass stabilization and erosion control. These ecosystem services are critical to helping reduce the risk that extreme weather, flooding and erosion creates material disruption to both transportation services and associated supply chains.

The transportation sector group's dependence on the climate regulation ecosystem service is primarily due to the sector group's vulnerability to climate-related disruption, which is lessened by the climate regulation ecosystem service.

A review of relevant assets within the transportation sector group of the S&P Global BMI was not performed due to data limitations.

Transportation is most dependent on the flood and storm protection ecosystem service

Nature dependency risk scores for the transportation sector group of the S&P Global BMI



Ecosystem services with a dependency score of 0 are omitted for clarity: animal-based energy, bioremediation, buffering and attenuation of mass flows, dilution by atmosphere and ecosystems, disease control, fibers and other materials, filtration, genetic materials, maintain nursery habitats, mediation of sensory impacts, pollination, soil quality, and water flow maintenance.
Ecosystem service definitions can be found at https://www.spglobal.com/esg/solutions/nature-risk-profile-methodology.pdf.
Source: S&P Global Sustainable1.

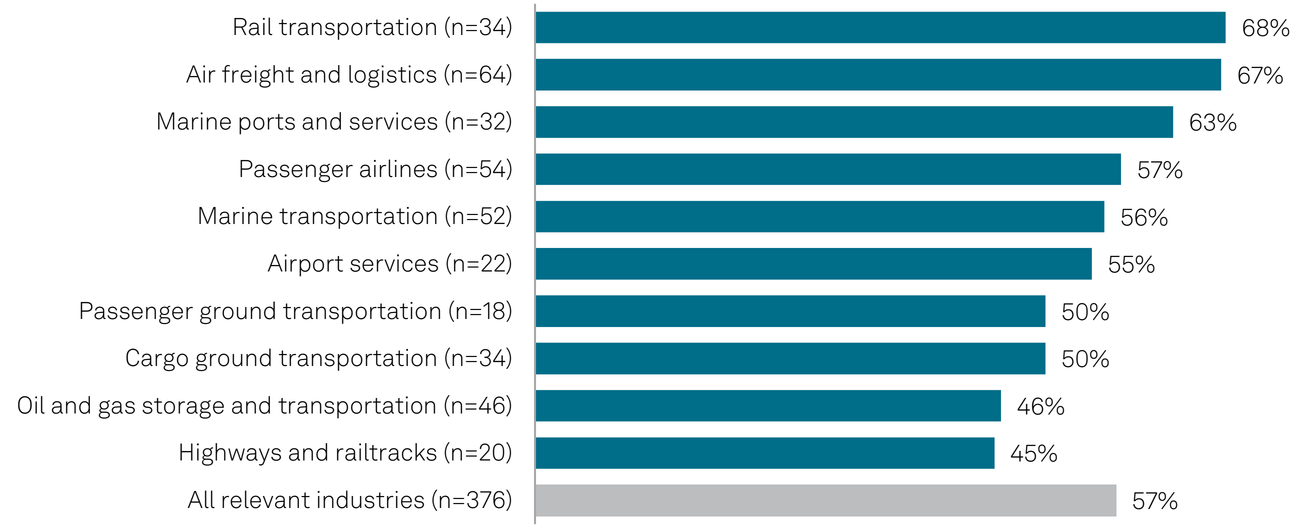
Workforce training for transportation

The transportation sector group faces trends that are changing the way companies operate and the skills they need from employees, including digitalization, automation and the use of alternative low-carbon energy sources, according to the European Commission.[55]

In the face of this transformation, upskilling employees and enhancing human capital across these sectors will be vital. Among companies in relevant industries assessed in the 2022 S&P Global Corporate Sustainability Assessment (CSA), 57% are providing some kind of employee development programs to upgrade and improve employee skills. These programs were most common in the rail transportation and air freight industries and least common in the oil and gas transportation and highways and railtracks industries.

57% of companies in relevant transportation industries have employee development programs

Percentage of assessed S&P Global BMI companies with employee development programs by industry



Results based on responses from 376 companies in the S&P Global BMI index assessed in the 2022 S&P Global Corporate Sustainability Assessment (CSA).
To read the full text of CSA criteria and questions, click here.
Source: S&P Global Sustainable1.

8.6 Crop cultivation and livestock production

Two of the six sector groups highlighted in this report are agricultural. Crop cultivation and livestock production generate the fifth- and sixth-highest environmental damage costs across the universe of S&P Global BMI companies, with total estimated environmental damage costs in 2021 of $143.9 billion and $75.3 billion, respectively. Unlike the other major sector groups, land use was the most significant impact for both crop cultivation and livestock production, at 47.7% and 41.8% of total environmental damage costs, respectively. Air pollution was the second-highest impact for these sector groups, representing 27.7% of environmental damage costs for crop cultivation and 41.0% of environmental damage costs for livestock production.

The land and water pollution impact and the water use impact represented notable shares of the total environmental damage costs from crop cultivation at 10.5% and 5.0%, respectively. Crop irrigation is a major source of water use globally, and fertilizer and pesticide runoff during rainstorm or when snow melts can contaminate local streams, rivers and groundwater.[56]

Globally and throughout company supply chains, agriculture represents some of the most significant harm to natural capital in terms of water and land use, pollution and GHGs. This analysis is limited to the direct operations of companies in the S&P Global BMI and therefore does not fully capture the impact of agricultural activities globally.

Impacts from crop cultivation sectors ($B)

Source: S&P Global Sustainable1.

8.6.1 Crop cultivation

The crop cultivation sector group includes the cultivation of oilseeds; the cultivation of vegetables, fruits and nuts; the cultivation of cereal grains; the cultivation of sugar cane; and the cultivation of cotton and other plant-based fibers.

The cultivation of oilseeds sector accounts for 70.1% of total environmental damage costs in crop cultivation, which is about $101.0 billion. The second-highest sector is cultivation of cereal grains, with $26.5 billion in environmental damage costs. The large difference in environmental damage costs between these two sectors is partly due to oilseeds' larger revenue share in the S&P Global BMI universe of companies. Among these companies, revenue from the cultivation of oilseeds is more than five times larger than revenue from cultivating cereal grains.

For crop cultivation, 75.8% of the environmental damage costs occur in Eastern Asia, Southeastern Asia and Northern America combined. More specifically, the cultivation of oilseeds in Southeastern Asia and Eastern Asia together represents a majority (55.4%) of the environmental damage costs from the entire crop cultivation sector group.

Every major sector-region for the crop cultivation sector group has an impact ratio greater than 1, meaning that the unpriced natural capital costs they generate are greater than the revenue they generate in that region. If environmental costs were fully internalized by the sectors in these regions, those costs would fully overtake revenue — and in some sector-regions, such as cereal grain cultivation in Eastern Asia, the costs would be more than double total revenue.

One oilseed in particular, palm oil, has been associated with deforestation and the draining of peatlands, which has implications for both CO_2 emissions and biodiversity. Peatlands and forests play a critical role in absorbing GHGs.

Of all sectors reviewed in this report, the cultivation of oilseeds has the highest environmental damage costs for land use at $54.6 billion, representing almost one-third of the total land use impact across the entire S&P Global BMI.

10 highest damage cost crop cultivation sector-regions

Sector	Region	Damage cost ($B)	Impact ratio
Cultivation of oil seeds	Southeastern Asia	43.55	1.8
Cultivation of oil seeds	Eastern Asia	36.24	1.6
Cultivation of cereal grains	Eastern Asia	9.38	2.8
Cultivation of cereal grains	Northern America	5.93	1.8
Cultivation of cereal grains	South America	5.48	1.9
Cultivation of oil seeds	Northern America	5.01	1.2
Cultivation of oil seeds	Southern Asia	4.04	1.5
Cultivation of vegetables, fruit, nuts	Eastern Asia	3.56	1.0
Cultivation of oil seeds	Western Europe	3.12	1.8
Cultivation of all other crops	Southern Asia	2.19	2.5

Source: S&P Global Sustainable1.

Sector groups in depth

Converting forests to palm oil plantations can also result in increased introduction of fertilizers, pesticides and other runoff chemicals into streams and nearby waterways, ultimately affecting water quality and local biodiversity.[57] Palm oil is reported as a threat to 321 species on the International Union for Conservation of Nature's Red List of Threatened Species, including orangutans, gibbons and tigers.

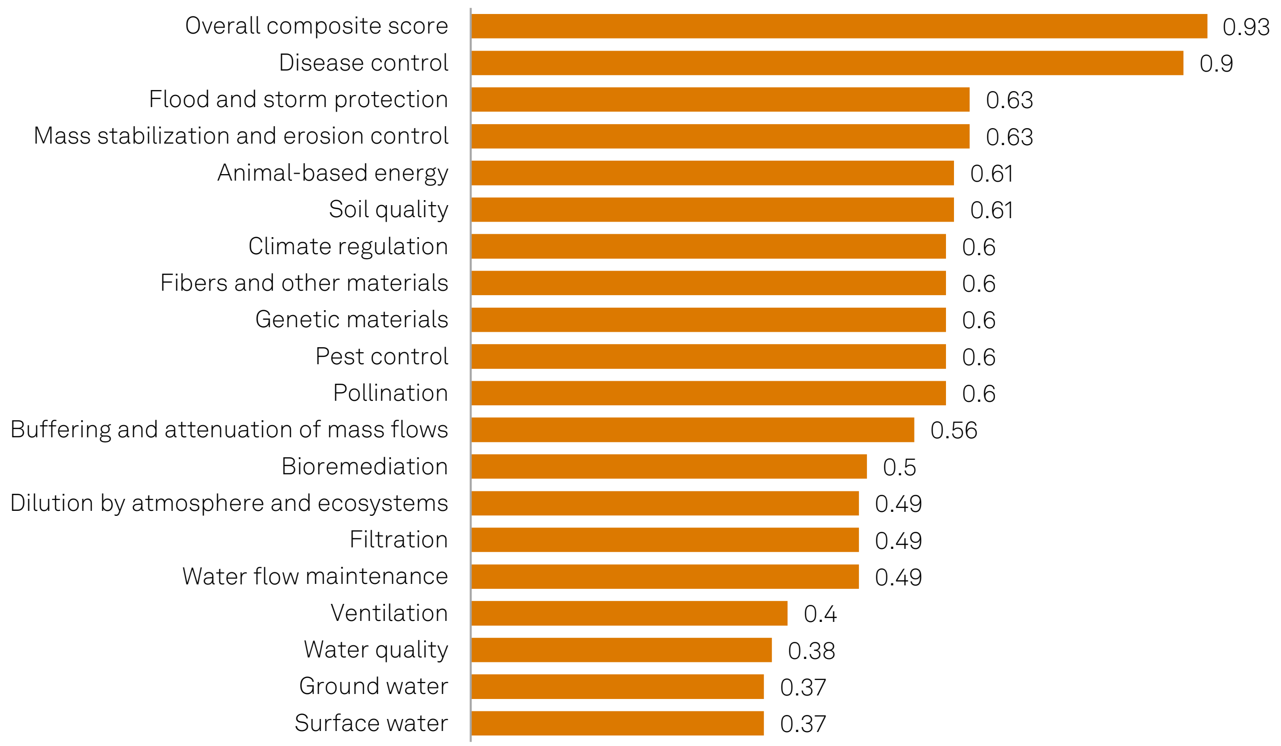
While land use plays the largest role in environmental damage costs from the cultivation of oilseeds, air pollution is its second-highest impact and makes up 27.7% of that sector's total environmental damage costs. The vast majority of oilseeds air pollution impact is from ammonia, with the remainder coming from particulate matter.

Agriculture accounts for 81% of ammonia emissions globally and reacts with other gases to create secondary fine particulate matter, which can cause acute and chronic respiratory illnesses in humans. Ammonia emissions from agriculture come from livestock and animal production and housing, as well as the handling, storage and application of manure and artificial fertilizers to land.[58]

Another source of agricultural ammonia is from the decay of crop residues — the parts of plants that remain on the field after a harvest, after being killed off by a frost, or from herbicide application.[59] In addition, ammonium nitrate fertilizers are a commonly used fertilizer for oilseed crops.[60]

Crop cultivation has very high dependency on ecosystem services

Nature dependency risk scores for the crop cultivation sector group of the S&P Global BMI



Ecosystem services with a dependency score of 0 are omitted for clarity: mediation of sensory impacts and maintain nursery habitats.
Ecosystem service definitions can be found at https://www.spglobal.com/esg/solutions/nature-risk-profile-methodology.pdf.
Source: S&P Global Sustainable1.

Sector groups in depth

Crop cultivation and nature risk

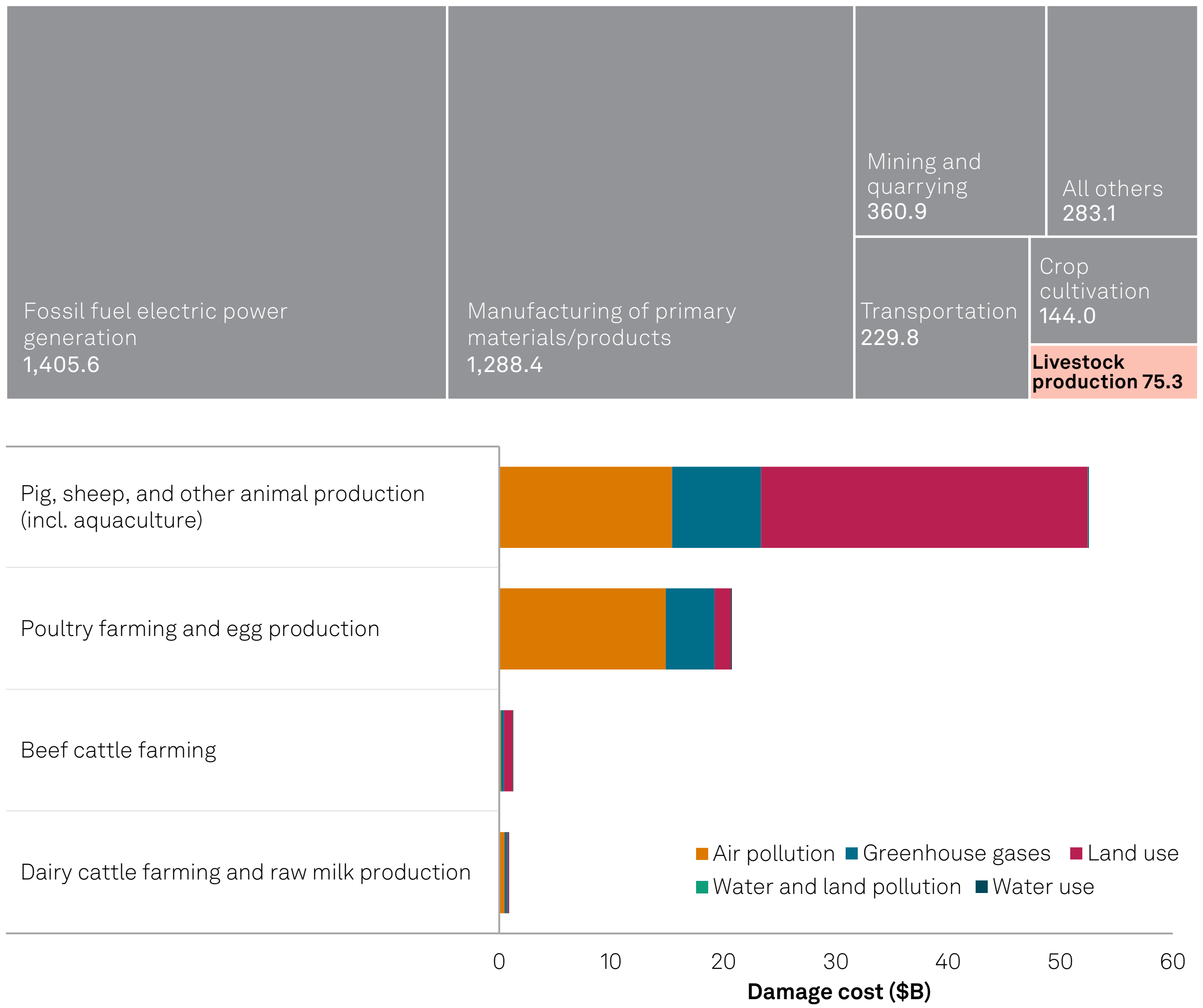
Crop cultivation has the highest nature risk dependency score of all the six sector groups highlighted in this report. Like most other sector groups, crop cultivation is highly dependent on mass stabilization and erosion control, flood and storm protection, and climate regulation. But crop cultivation is also highly dependent on ecosystem services tied to growing productive and healthy crops such as disease control, soil quality, genetic materials, pest control and pollination.

Pollination services are provided by water, wind and pollinators such as insects and birds, and most plant species depend on pollinators to grow. Pollination is needed for reproduction of up to 80% of all plant species and 35% of global crop production.[61] Yet the pollinator population, especially wild bees, is in decline.[62] The UN's Intergovernmental Panel on Climate Change (IPCC) in 2022 noted that a complete loss of pollinators could reduce global fruit supply by 23%, vegetables by 16%, and nuts and seeds by 22%, and also lead to a significant increase in the number of people with nutrient deficiencies and malnutrition-related diseases.[63]

Soil quality ecosystem services maintain the bio-geochemical conditions of soils, including fertility and soil structure, and decomposition and soil fixing processes, which enable nitrogen fixing, nitrification and mineralization of dead organic material that plants need to grow and thrive.

8.6.2 Livestock production

Impacts from livestock production sectors ($B)



Source: S&P Global Sustainable1.

For the livestock production sector group, land use (41.8%) and air pollution (41.0%) are the most significant impacts, followed by GHGs (16.9%).

Livestock production includes pig, sheep and other animal production (including aquaculture), poultry farming and egg production, dairy cattle farming and raw milk production, and beef cattle farming.

Pig, sheep and other animal production has the highest environmental damage costs within the sector group, contributing to 69.7% of the total. The large difference in environmental damage costs between the pig, sheep and other animal production sector and poultry farming is mostly explained by the land use impact, followed by GHGs.

Environmental damage costs due to land use for the animal production sector group are more than 19 times higher than for the poultry and egg production sector, and GHG environmental damage costs are about 1.8 times higher.

This analysis is limited to the direct operations of companies listed in the S&P Global BMI and therefore does not represent the full impact of livestock sectors such as cattle farming on anthropogenic climate change, as much of this impact occurs upstream in the value chain of publicly listed companies. Deforestation for cattle grazing is especially significant in Brazil and other Amazon rainforest countries. Brazil's beef exports in 2020 represented 339.2 million metric tons of CO_2 emissions due to deforestation.[64] Deforestation is also a major driver of biodiversity loss globally, as forests provide habitats for 60% of vascular plant species, 68% of mammal species, 75% of bird species and 80% of amphibian species.[65] Commercial agriculture, primarily cattle raising and the cultivation of soy and palm oil represented 40% of deforestation between 2000 and 2010.[66]

Globally, the primary source of GHGs from livestock directly is methane mostly produced by ruminant animals such as cattle, sheep and goats, which have a digestive system that involves fermentation in their rumen. This process can produce significant amounts of methane, and depending on the livestock diet, higher nitrogen excretion. Methane is a more potent GHG than CO_2 in terms of its ability to retain heat in the atmosphere, and therefore has an outsized impact on global warming. The UN Environment Programme estimates that livestock emissions from manure and gastroenteric releases make up about 32% of human-caused methane emissions.[67]

10 highest damage cost livestock production sector-regions

Sector	Region	Damage cost ($B)	Impact ratio
Pig, sheep, and other animal production (incl. aquaculture)	Eastern Asia	46.5	1.5
Poultry farming and egg production	Eastern Asia	15.7	0.9
Pig, sheep, and other animal production (incl. aquaculture)	Southeastern Asia	2.2	2.0
Poultry farming and egg production	Southeastern Asia	1.6	0.2
Poultry farming and egg production	Northern America	1.4	0.4
Pig, sheep, and other animal production (incl. aquaculture)	Northern Europe	0.9	0.7
Dairy cattle farming and raw milk production	Eastern Asia	0.8	0.7
Pig, sheep, and other animal production (incl. aquaculture)	Western Europe	0.8	1.2
Beef cattle farming	Eastern Asia	0.7	2.3
Pig, sheep, and other animal production (incl. aquaculture)	Northern America	0.7	1.1

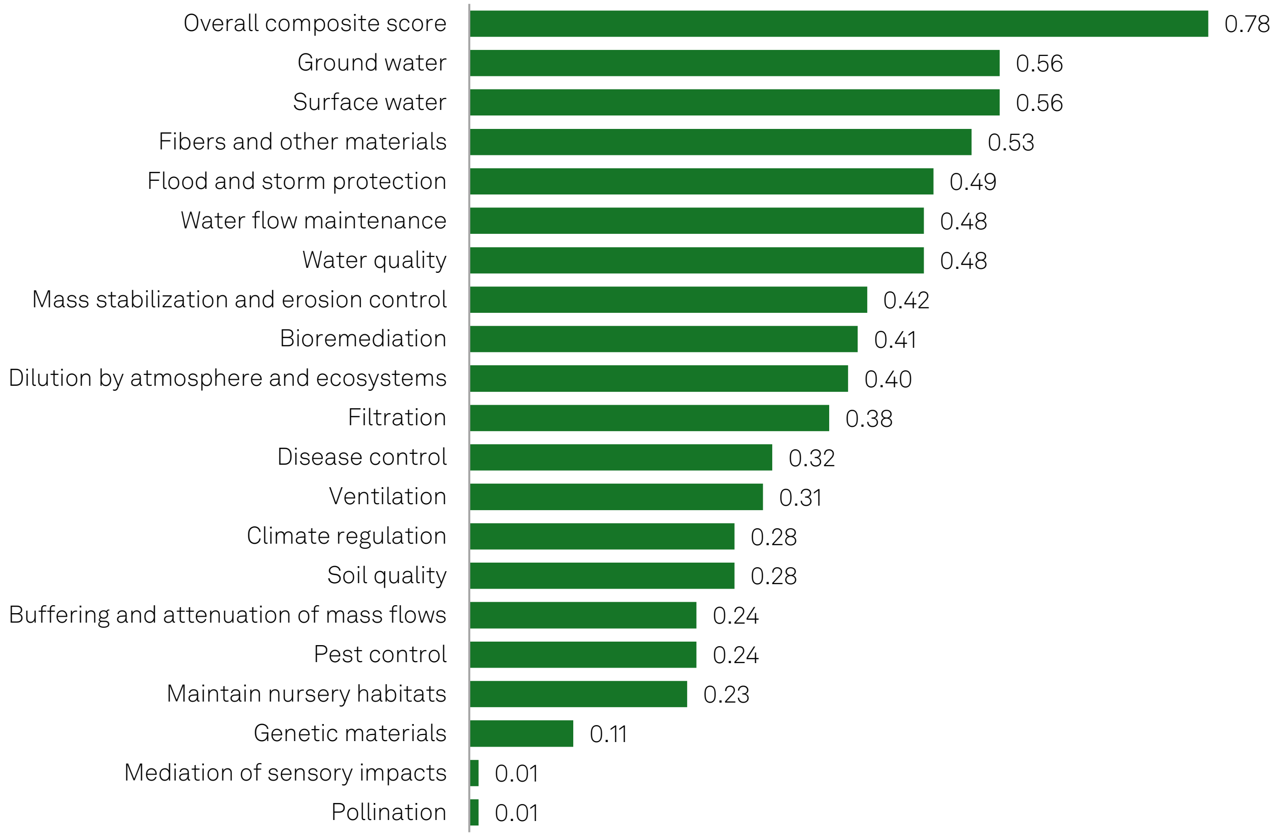
Source: S&P Global Sustainable1.

Livestock production and nature risk

Livestock production is highly dependent on nature's ecosystem services, particularly ground and surface water as well as fibers and other materials, flood and storm protection, bio-remediation and mass stabilization and erosion control. Raising livestock requires a reliable supply of clean freshwater, which is also impacted by the ecosystem services of water flow maintenance, water quality and filtration.

Livestock production is most dependent on ground and surface water

Nature dependency risk scores for the crop cultivation sector group of the S&P Global BMI



Ecosystem services with a dependency score of 0 are omitted for clarity: animal-based energy.
Ecosystem service definitions can be found at https://www.spglobal.com/esg/solutions/nature-risk-profile-methodology.pdf.
Source: S&P Global Sustainable1.

9. Looking forward

This report shines a light on the hidden environmental costs embedded within our economic system, serving as a catalyst for change. The findings demonstrate that immediate action is required.

Several issues remain unresolved, and much work needs to be done. We encourage a more encompassing, rigorous and systematic way to address land use impact. Doing so would support efforts to address biodiversity-related impacts and dependencies, as well as risks and opportunities, in alignment with Sustainable Development Goal 15 — to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. A more granular, encompassing analysis at the company level will provide a deeper understanding and momentum for action toward transformation. Increasing transparency on methodological approaches is critically important to generate trust and confidence in the generated information.

We need to move beyond a siloed view and embrace a holistic perspective that integrates the value of nature, people, society and finance into every decision. This means setting ambitious targets and ensuring accurate disclosure of environmental impact, not just for the sake of compliance but to gain a deeper understanding of the risks and opportunities that lie ahead.

Businesses must prioritize environmental responsibility and transform it from a voluntary best practice to an essential component of risk management. Investors need to assess the environmental risks associated with specific business activities and regions. Policymakers must accelerate the transition away from fossil fuels and prioritize tackling the most severe environmental challenges. Ultimately, we must recognize that our economy exists to meet human needs in a sustainable way. This requires a collaborative effort from businesses, governments, and finance, all working together to build a more sustainable and equitable future for all.

Our economy is a function we have created to understand the world and to meet our needs. It is obvious from this report that the economic system needs an update.

The time to value what matters is now.

—Capitals Coalition

10. Appendices

10.1 Appendix 1: Sector groups

Activities of membership organizations n.e.c.
Activities of membership organizations n.e.c.
Auxiliary transport and storage activities
Auxiliary transport activities
Warehousing and storage
Business services
Administrative and support services
Computer and related services
Management holding companies and other corporate, subsidiary, and regional managing offices
Professional, scientific, and technical services
Research and development
Construction
Construction
Crop cultivation
Cultivation of all other crops
Cultivation of cereal grains
Cultivation of cotton and other plant-based fibers
Cultivation of oilseeds
Cultivation of sugar cane, sugar beet
Cultivation of vegetables, fruit, nuts
Greenhouse, nursery, and floriculture production

10.1 Appendix 1: Sector groups *continued*

Distribution of gaseous fuels through mains
Distribution of gaseous fuels through mains
Education
Education
Electric power transmission and distribution
Distribution and trade of electricity
Transmission of electricity
Financial intermediation
Funds, trusts, and other financial vehicles
Insurance
Monetary authorities and depository credit intermediation
Nondepository credit intermediation and related activities
Securities, commodity contracts, investments, and related activities
Fossil fuel electric power generation
Production of electricity by coal
Production of electricity by gas
Production of electricity by petroleum/oil derivatives
Health and social work
Ambulatory health care services
Hospitals
Nursing and residential care facilities
Social assistance
Veterinary services

10.1 Appendix 1: Sector groups *continued*

Manufacturing of primary materials/products
Asphalt product manufacturing
Casting of metals
Concrete product manufacturing
Manufacture of all other chemical products
Manufacture of all other non-metallic mineral products
Manufacture of aluminium
Manufacture of basic chemicals
Manufacture of beverages
Manufacture of bricks, tiles, and clay construction products
Manufacture of cement, lime and plaster
Manufacture of ceramic goods
Manufacture of copper
Manufacture of fabricated metal products (except machinery and equipment)
Manufacture of fertilizers, pesticides, and other agricultural chemicals
Manufacture of food products
Manufacture of glass
Manufacture of glass products
Manufacture of iron, steel and ferroalloys
Manufacture of leather
Manufacture of leather products
Manufacture of other petroleum and coke oven products
Manufacture of paper
Manufacture of paper products
Manufacture of pharmaceuticals and medicines
Manufacture of plastic products
Manufacture of plastics material, resin, and synthetic rubber
Manufacture of rubber products
Manufacture of textile products
Manufacture of textiles
Manufacture of titanium, zinc, other non-ferrous metal
Manufacture of tobacco products
Manufacture of wearing apparel
Manufacture of wood
Manufacture of wood products (except furniture)
Petroleum refining

10.1 Appendix 1: Sector groups *continued*

Mining and quarrying
Extraction of crude petroleum and natural gas
Mining and agglomeration of coal and lignite
Mining of aluminium ores and concentrates
Mining of copper ores and concentrates
Mining of iron ores
Mining of lead, zinc and tin ores and concentrates
Mining of nickel ores and concentrates
Mining of other non-ferrous metal ores and concentrates
Mining of other non-metallic minerals
Mining of uranium and thorium ores
Quarrying of sand and clay
Quarrying of stone
Specialised support services for mining and quarrying
Nuclear electric power generation
Production of electricity by nuclear
Personal service activities
Personal service activities
Postal and courier services
Couriers and messengers
Postal service
Printing, publishing and reproduction of recorded media
Printing
Publishing
Reproduction of sound, video and computer media

10.1 Appendix 1: Sector groups *continued*

Real estate activities
Real estate activities
Recreational, cultural and sporting activities
Amusement, gambling, and recreation activities
Broadcasting and content providers
Libraries, archives, and related activities
Motion picture and video industries
Museums, historical sites, zoos, and parks
Performing arts, spectator sports, and related activities
Renewable and other electric power generation
Production of electricity by biomass
Production of electricity by geothermal
Production of electricity by hydro
Production of electricity by landfill gas
Production of electricity by solar
Production of electricity by tide, wave, ocean
Production of electricity by wind
Production of electricity n.e.c.
Renting of machinery, equipment, and personal and household goods
Automotive equipment rental and leasing
Commercial and industrial machinery and equipment rental and leasing
General and consumer goods rental

10.1 Appendix 1: Sector groups *continued*

Telecommunications
Telecommunications
Transportation
Air transportation
Pipeline transportation
Rail transportation
Road transportation
Water transportation
Waste management services
Waste management services
Water supply and sewerage
Water supply and sewerage
Wholesale and retail trade
Wholesale and retail trade

10.2 Appendix 2: Methodology and EKPIs considered

This Appendix describes the underlying methodologies used to derive the insights of the report “Unpriced Environmental Costs: The Top Externalities of the Global Market.” The table below outlines how each methodology has been applied.

Table 1: Appendix Contents

Methodology	Data Analyzed		Derived Outputs	Appendix Section
Natural Capital Impacts *Environmental Damages as Monetary Costs to Society*	S&P Global BMI	Company data in all sectors	US$M (2021) of environmental impact based on metric ton, m², or m³ of EKPI emitted/used	**10.2.1**
Nature Dependency Risks	S&P Global BMI	Company/asset data in selected sector groups: - Fossil fuel generation - Manufacturing of primary materials - Mining and quarrying - Transportation - Crop cultivation - Livestock production	Nature Dependency Scores based on company/asset type and location	**10.2.2**
Human & Social Impacts	S&P Global BMI	S&P Global Corporate Sustainability Assessment company-level data in selected sector groups: - Manufacturing of primary materials - Mining and quarrying - Transportation	Qualitative analysis of disclosed data values	**10.2.3**

10.2.1 Natural Capital Impacts

The results in this report represent an analysis of the environmental impacts of the S&P Global Broad Market Index (BMI), with insights derived from reviewing the environmental profiles of more than 12,000 listed companies across the global economy (98% of the index weight).

Results were derived by combining real company environmental disclosures with S&P Global Sustainable1’s proprietary environmental profiling model, to estimate the full spectrum of corporate-driven environmental impacts in the absence of disclosure. These impact quantities were monetized, where applicable, using S&P Global Sustainable1’s core database of environmental damage costs, to estimate the associated magnitude of natural capital cost, in monetary terms. These costs are not directly observable in the market due to their varied forms, such as localized chemical pollution, noise pollution and visual nuisance, among many others.

Company data was aggregated and assessed across sectors, regions and environmental key performance indicators (EKPIs), including individual chemical pollutant emissions and resource use. Revenue-based environmental intensity factors were used when disclosed data was not available to estimate companies resource use and emissions across their direct operations, based on reported sector revenue breakdown, to provide a holistic view of each company’s environmental profile. S&P Global Sustainable1’s latest environmental damage cost factors were then applied to the disclosed (and/or estimated) quantities of pollutant emission and resource use.

The environmental damage cost factors convert unpriced company impacts on natural capital into monetary terms, enabling comparison and assessment of business practices in a systematic way based on value creation and destruction. The environmental damage costs are based largely on peer-reviewed academic studies and datasets, covering the major environmental externalities associated with each type of economic activity (see Appendix 10.1).

Finally, the total damages were aggregated to derive summary statistics, providing insights into the overall performance and environmental footprint of sectors and regions.

10.2.1.1 Natural Capital Impacts: Scope of the Analysis

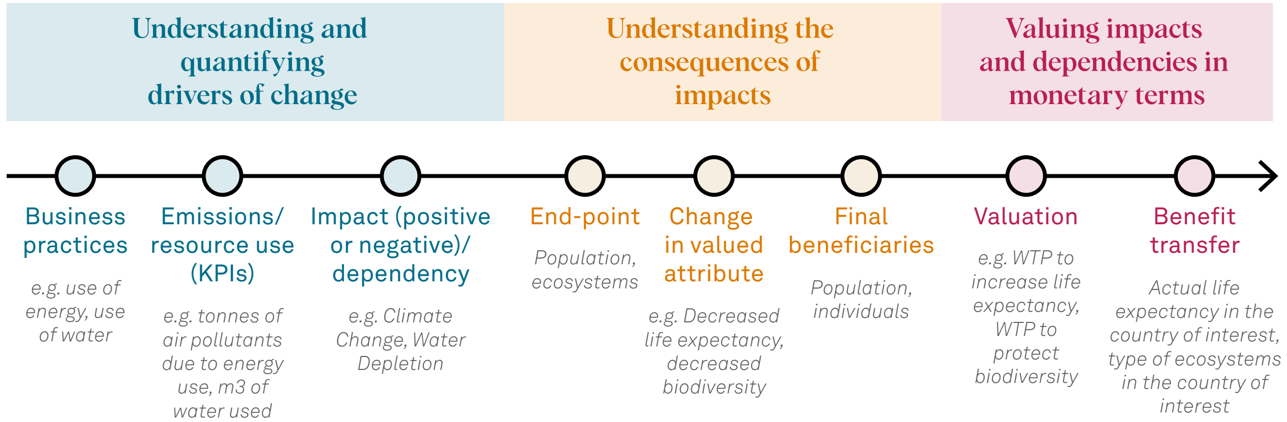
This report organizes the environmental impacts translated to damage costs into six categories, referred to as EKPIs: greenhouse gas emissions (GHGs); air pollution; land and water pollution; waste; land use; and water use. The environmental valuation methodology was used to translate the impacts associated with company-driven environmental emissions and resource use (by sector region) into monetary values referred to as “environmental damage costs.” The following figure provides an overview of the scope covered by the environmental valuation methodology used in this report to derive the total environmental impacts of companies in the S&P Global BMI, in monetary terms. The overall environmental valuation methodology has six modules. The underlying individual methodologies used to derive each EKPI are explained in the following Appendix sub-sections. The air pollution and land and water pollution EKPIs’ underlying methodologies have been grouped under the same section in this appendix for conciseness, as both pertain to the release of pollutants.

Figure 1: Scope of environmental valuation methodology

As of June 2024.
GHGs = Greenhouse gases.
Overview of the scope covered by the environmental valuation methodology to calculate the environmental impacts of companies in monetary terms.
* See air pollution and land and water pollution methodology section.
Source: S&P Global Sustainable1.

10.2.1.2 Natural Capital Impacts: Assessment Framework

Figure 2: Overview of the assessment framework



As of June 2024.
Source: S&P Global Sustainable1.

The framework used to derive the environmental damage costs includes three analysis steps that establish the link between impacts and changes in the condition of specific societal groups, such as local communities, employees, businesses and the wider society.

Figure 2 above highlights the three steps taken in the methodology to derive environmental damage costs.[68]

10.2.1.2.1 Understanding and Quantifying Drivers of Change

The first step is to understand the drivers of change by identifying a set of key performance indicators (KPIs) that measure the extent of impacts. This involves a thorough materiality assessment to identify the major drivers of impact across the entire corporate value chain, leveraging existing research and bespoke consultancy work. Material KPIs (i.e. EKPIs) are then quantified via company disclosure or, in the absence of disclosure, via various estimation/modelling techniques to gap-fill missing data on environmental emissions and resource use. Estimation techniques include (i) extrapolation from previous year, (ii) application of GHG/air pollutant emission factors to disclosed fuel use, and (iii) application of environmentally extended input output (EEIO) modelling[69], among others.

10.2.1.2.2 Understanding the Consequences of Impacts

The second step is to understand the consequence of the impact to a specific end-point. An end point is the primary receptor of the impact — society, the environment, or the business itself. Each impact can have several end-points. For example, water depletion (negative impact) can affect society (end point 1) through lack of drinking water and decreased food supply, and the environment (end point 2) through decreased water availability to sustain fauna and flora. It can also affect the business itself (end point 3) through reduced freshwater availability, which may constrain company operations in specific locations. Examples of impact metrics, or “valued attributes,” are changes in life expectancy or changes in species richness due to the emission of pollutants. Complex biophysical models are used to estimate these metrics, based on a thorough literature review, and adapted to reflect local conditions.

10.2.1.2.3 Valuing Impacts in Monetary Terms

The third and final step consists of converting the impact metrics into monetary terms that reflect the costs and benefits to specific beneficiaries of the change in valued attribute. The output of this step is a damage cost (also referred to as a valuation coefficient) that reflects cost or benefit of specific practices and associated use of inputs and emissions on natural and social capital.

A key consideration is that regardless of the end point, the costs and benefits are anthropogenic, even in the case where the end-point is the environment. For example, the costs and benefits of a change in biodiversity are valued based on the services that biodiversity provides to society.

Several techniques exist to assign a value to a change in valued attribute and calculate the costs and benefits in monetary terms of a specific action (see Table 1: Appendix Contents Table 2 for an overview). Techniques span from observing behaviour on existing alternative markets as a proxy — for example, how much is spent on aquatic recreational activities, or creating artificial markets by asking a population their willingness-to-pay (WTP) for the existence of wildlife habitat.

S&P Global Sustainable1 therefore chose valuation techniques based on data availability and suitability, ensuring consistency across all end points. For example, the change in life expectancy has been valued the same regardless of whether it is caused by malnutrition due to water depletion, or by the ingestion of contaminated food due to water pollutants.

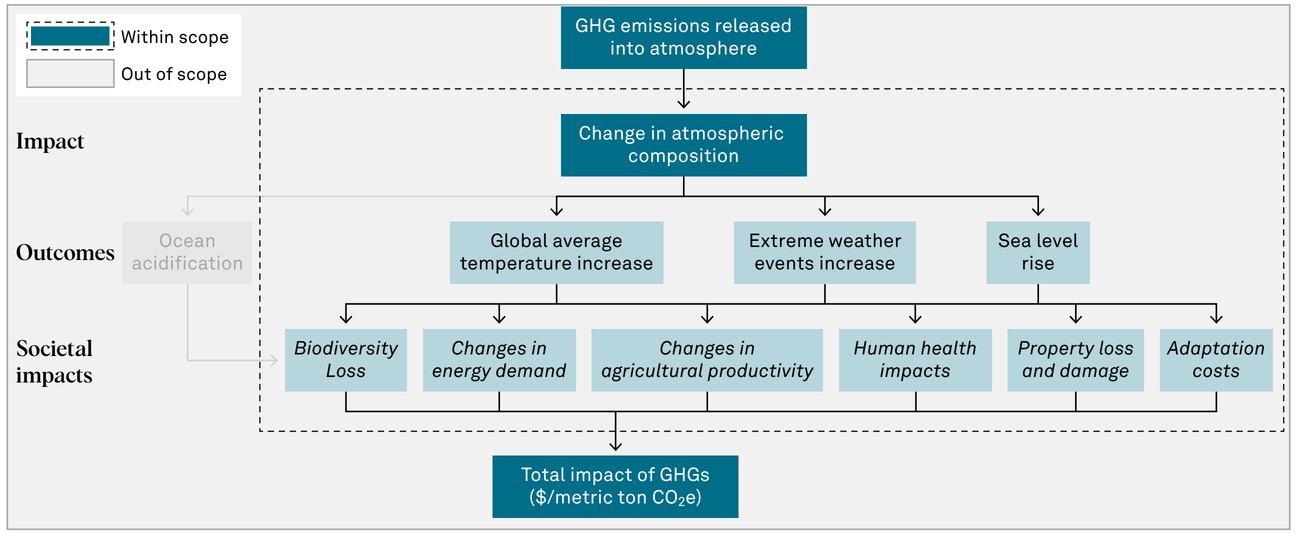
Since the values are highly contigent on local conditions, in order to estimate costs or benefits in a context when no local study exists, S&P Global Sustainable1 relies on the value transfer method. This method uses a primary valuation in one location, called the study site, and estimates the value for the same attribute in another location, called the policy site, based on one or more key variables that explain the value of the attribute. The methods used for each EKPI to derive environmental damage costs in this report are summarized in the following sections.

Table 2: Overview of existing valuation methodologies

Valuation technique	Description
Abatement cost	The cost of removing a negative by-product to achieve a target for example, by reducing the emissions or limiting their impacts.
Avoided cost/ replacement cost/ substitute cost	Estimates the economic value of environmental impacts based on either the costs of avoiding damages due to lost environmental attributes, the cost of replacing these attributes, or the cost of providing substitute attributes. Most appropriate in cases where damage avoidance or replacement expenditures have or will be made.
Contingent valuation	A survey-based technique for valuing non-market resources. This is a stated preference/ WTP model in that the survey determines how much people will pay to maintain an environmental feature.
Direct market pricing	Estimates the economic value of ecosystem products or environmental attributes that are bought and sold in commercial markets. This method uses standard economic techniques for measuring the economic benefits from marketed goods based on the quantity purchased and supplied at different prices. This technique can be used to value changes in the quantity or quality of a good or service.
Hedonic pricing	Estimates the economic value of environmental features that directly affect the market price of another good or service. For example proximity to open space may affect the price of a house.
Production function	Estimates the economic value of ecosystem products or environmental features that contribute to the production of commercially marketed goods. Most appropriate in cases where the products or services of an ecosystem are used alongside other inputs to produce a marketed good.
Site choice/ travel cost method	A revealed preference/WTP model which assumes people make trade-offs between the expected benefit of visiting a site and the cost incurred to get there. The cost incurred is the person’s WTP to access a site. Often used to calculate the recreational value of a site.

Source: S&P Global Sustainable1.

Figure 3: Overview of S&P Global Sustainable1 impact pathway for greenhouse gas emissions



As of June 2024.
Source: S&P Global Sustainable1.

10.2.1.3 Natural Capital Impacts: Greenhouse Gas (GHG) Emissions

S&P Global Sustainable1 considers the impact of the GHGs covered in the GHG Protocol, plus any other major GHG contributors in each sector. The UN Intergovernmental Panel on Climate Change (IPCC) reports have been used for the global warming potentials (GWPs)[70,71,72]. The valuation of the damage caused in monetary terms has then been calculated by multiplying companies' estimated GHG emissions in carbon dioxide equivalent (CO_2e) by the social cost of carbon (SCC) recommended by the Interagency Working Group on Social Cost of Greenhouse Gases (IWG)[73], and then aggregating these totals up to sector level.

The SCC, marginal abatement cost (MAC) and the market price of carbon in existing emissions trading schemes are common approaches that can be used to value the marginal cost of each additional metric ton of GHG emitted (usually expressed in metric tons of CO2e). Even though the three methods differ significantly in their current estimates of cost, in theory and perfect market conditions, all three approaches should lead to a similar value.

S&P Global Sustainable1 uses the SCC rather than MAC or the market price in this report, as it reflects the full global cost of the damage generated by GHG emissions over their lifetime, and as such, is typically considered best practice. SCC is also applicable to emissions globally, which is not the case with either the market price method or the MAC. However, SCC valuations are highly contingent on assumptions, in particular the discount rate chosen, emission scenarios and equity weighting.

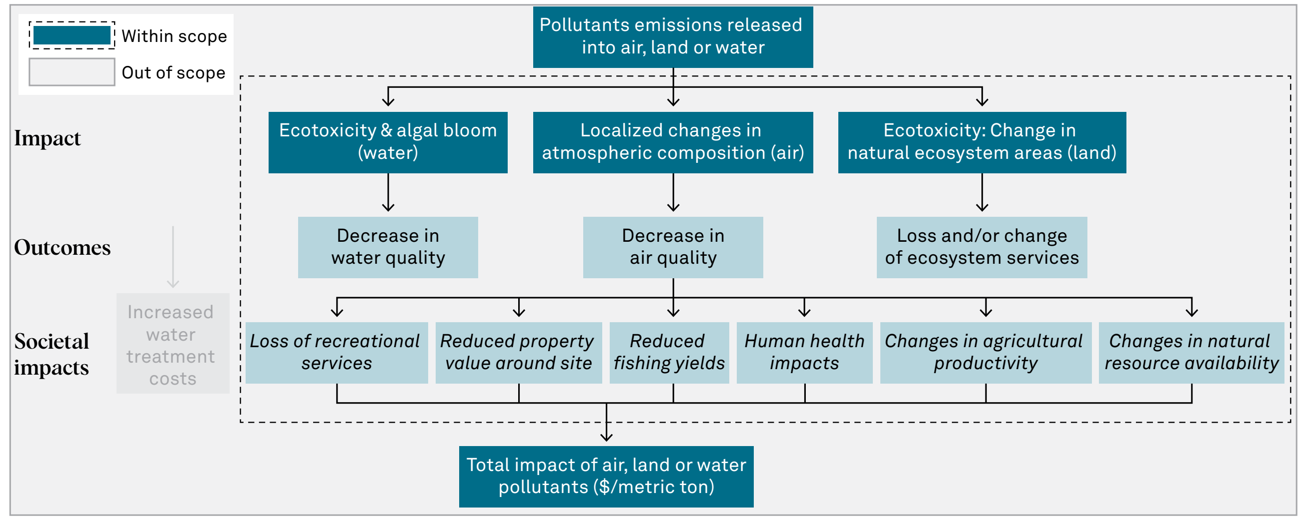
S&P Global Sustainable1 used the SCC values by the IWG (2016) and reported at the 95th percentile under a 3% discount rate, which represents higher-than-expected impacts from temperature change.

10.2.1.4 Natural Capital Impacts: Air, Land, and Water Pollution

Environmental pollution is caused by the emission of pollutants that affect air, fresh and marine waters, and natural and agricultural land. Each pollutant is associated with different, but overlapping, types of impact: some effects are caused directly by the primary pollutant (for example, the impacts of particulates on health), and some are caused by secondary pollutants, formed in the atmosphere as a result of the emission of primary pollutants that act as precursors.

The methodology places value on the impact of organic, heavy metal and other inorganic pollutants on human health and on ecosystems. The methodology under this section refers to two EKPIs: air pollution, and water and land pollution.

Figure 4: Overview of S&P Global Sustainable1 impact pathway for air, land and water pollution



As of June 2024.
Source: S&P Global Sustainable1.

10.2.1.4.1 Measuring human health impacts in terms of DALYs

- For the impact on human health, the Disability Adjusted Life Years (DALYs) quantification as set out by the World Health Organization (WHO, 2020)[74] has been used. A DALY can be thought of as one year of life in full health, with a DALY value of less than one representing a year of life spent in sub-optimal health.

10.2.1.4.2 Valuation of key criteria air pollutants

- The impacts of key criteria air pollutants including PM10, PM2.5, NH3, SOx, NOx, NMVOCs, have been monetized according to human health impacts only.

- The valuation coefficients for these pollutants have been determined based on characterization factors quantifying the human health impacts associated with their emission in DALYs per kilogram of pollutant emitted and provided per region. The DALY value was then applied to these factors to obtain impacts in monetary terms for every country.

10.2.1.4.3 Valuation of other air, land and water pollutants.

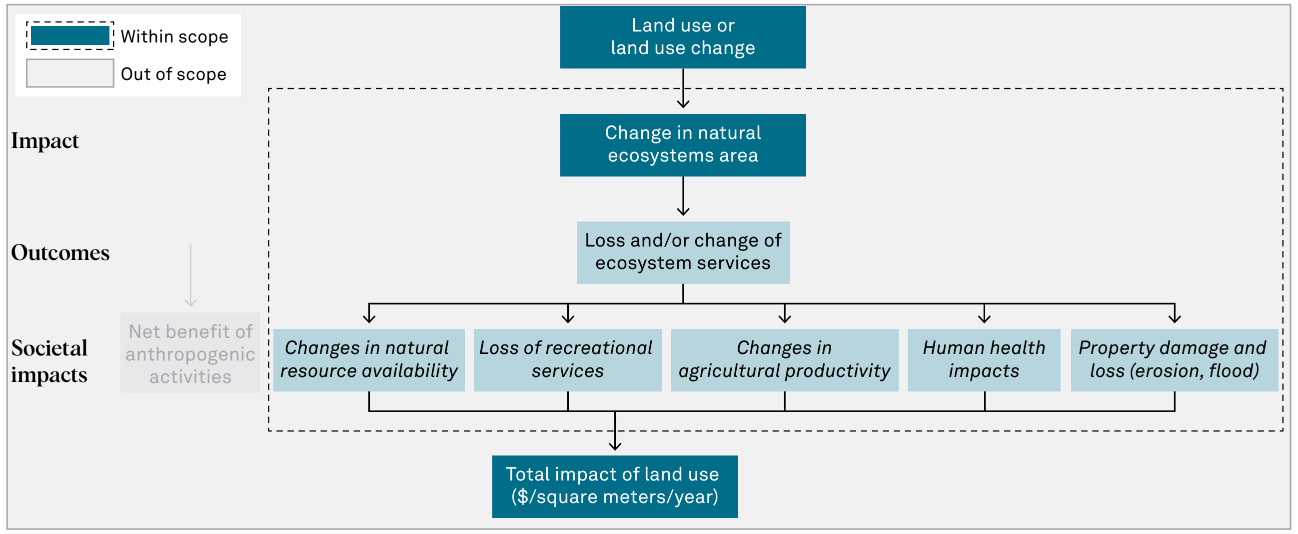
- The impacts of other air, land and water pollutants including heavy metals, pesticides, and other inorganic and organic pollutants, have been monetized according to their impacts on human health and ecosystems. The valuation coefficients were determined based on characterization factors representing the impacts of emitting 1 kg of chemical pollutant to air, land or water, on human health (in terms of DALYs) and on freshwater/seawater/terrestrial ecosystems (in terms of the percentage of ecosystem service value (ESV) lost, by pollutant and emission media.

10.2.1.5 Natural Capital Impacts: Land use

Land use change is a key direct driver of habitat and ecosystem loss that is degrading the stock of natural capital on which society relies (MA., 2005)[75]. The impacts of land use change are notably associated with the loss of ecosystem services, a concept promulgated by the Millennium Ecosystem Assessment (MA., 2005).

S&P Global Sustainable1's methodology assesses the loss of ecosystem services due to the conversion of land from its natural ecosystem to an alternative land use or state, focusing on the ecosystem services that are provided by terrestrial ecosystems. Land use valuation coefficients have been generated to represent the expected loss of terrestrial ESV associated with four different types of anthropogenic land occupation: crop land, pastureland, plantation forest land, and infrastructure land. The impact of this land occupation on terrestrial ecosystems is then monetized, for each land occupation type, in each country.

Figure 5: Overview of S&P Global Sustainable1 impact pathway for land use change



As of June 2024.
Source: S&P Global Sustainable1.

10.2.1.5.1 Estimating ecoregion distribution

- The terrestrial area covered by each ecosystem in each country was calculated by mapping the ecosystem categories to Geographic Information System (GIS) datasets representing country administrative boundaries and global ecoregions. These datasets were spatially joined to calculate the share of each terrestrial ecoregion within each country's land boundary.

10.2.1.5.2 Monetizing the impacts of land use change

- Land use, in this methodology, is defined as any occupation of land that exists in place of natural ecosystems. The average of marginal values of ecosystem services (over all time) is used instead of the current marginal value. This takes into account the fact that the timing of land conversion is unknown with respect to the timespan, from when there was zero ecosystem service scarcity to present-day levels of scarcity.

- The monetary value of an ecosystem is estimated by combining the value of the various individual ecosystem services it provides[76]. For each biome, the median marginal ecosystem service values for all material (and mutually exclusive) ecosystem services were summed based on materiality, accounting for services benefiting the global population and those benefitting only the local population. These two categories were further subdivided depending on whether the ecosystem service is likely to be fully or partially lost as a result of land occupation for corporate purposes. "Fixed" ecosystem services are assumed to be completely lost as a result of land occupation. "Variable" ecosystem services are assumed to be partially lost, to a differing extent, depending on the specific type of land occupation (for example, pasture or forest land occupation).

- The identified local portion of ESV lost based on De Groot et al. (2012) was transferred across countries based on the difference in income level between each country in 2021 and the reference year. Similarly, the global portion of ESV was transferred based on the difference in the population weighted global average income level, using Gross National Income (GNI) per capita, between 2021 and reference year. Both the local and global portions of ESV were then inflated to current (2021) year price levels.

Table 3: Ecosystem services assessed in S&P Global Sustainable1's methodology based on De Groot et al. (2012)

	Marine	Coral reefs	Coastal systems	Coastal wetlands	Inland wetlands	Freshwater (rivers/lakes)	Tropical forest	Temperate & boreal forest	Woodlands	Grasslands	Tundra	Desert
Provisioning services												
Food	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
(Fresh) water supply				Y	Y	Y	Y	Y		Y	Y	Y
Raw materials	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y
Genetic resources		Y		Y			Y					
Medicinal resources				Y	Y		Y			Y		
Ornamental resources		Y			Y				Y			
Regulating services												
Influence on air quality							Y					
Climate regulation	Y	Y	Y	Y	Y		Y	Y	Y	Y		
Moderation of extreme events		Y		Y	Y		Y					
Regulation of water flows					Y		Y					
Waste treatment/ water purification		Y		Y	Y	Y	Y	Y	Y	Y	Y	Y
Erosion prevention		Y	Y	Y	Y		Y	Y	Y	Y	Y	Y
Nutrient cycling/ maintenance of soil fertility				Y	Y		Y	Y				
Pollination							Y		Y			
Biological control					Y		Y	Y				
Habitat services												
Lifecycle maintenance (esp. nursery service)		Y	Y	Y	Y		Y		Y			
Gene pool protection (conservation)	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y
Cultural services												
Aesthetic information		Y			Y					Y	Y	Y
Opportunities for recreation and tourism	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Inspiration for culture, art and design		Y			Y							
Spiritual experience			Y									
Cognitive information (education and science)		Y	Y					Y				

As of June 2024.
Y = yes.
Source: S&P Global Sustainable1.

10.2.1.6 Natural Capital Impacts: Water use

Water availability can be affected when demand for water exceeds the volume available over a certain period of time, usually occurring in locations with low rainfall and high population density, or with strong agricultural and industrial operations. An unsustainable rate of water abstraction can affect access to water for local populations, provoke the intrusion of salt water in groundwater sources and, in more extreme situations, lead to the disappearance of water bodies and wetlands[77].

S&P Global Sustainable1 estimates the cost of using water, in different regions, at different levels of water scarcity, and for different use cases, accounting for the balance between water withdrawal and water consumption requirements.

The water withdrawal damage costs reflect the discounted future cost of groundwater depletion and the cost of water subsidies (GWI, 2019[78]; FAO AQUASTAT, 2022[79]; Zhou & Tol 2005[80]; Richey et al., 2015[81]; Gassert et al., 2013[82]; the World Bank, 2005[83]).

- The groundwater depletion cost was estimated as the discounted future cost of replacing groundwater supply, in the first year after each country's groundwater reserves are projected to be effectively depleted. These replacement costs are estimated based on the expected cost of alternative freshwater production, via seawater desalination and subsequent distribution to each country's population centers.

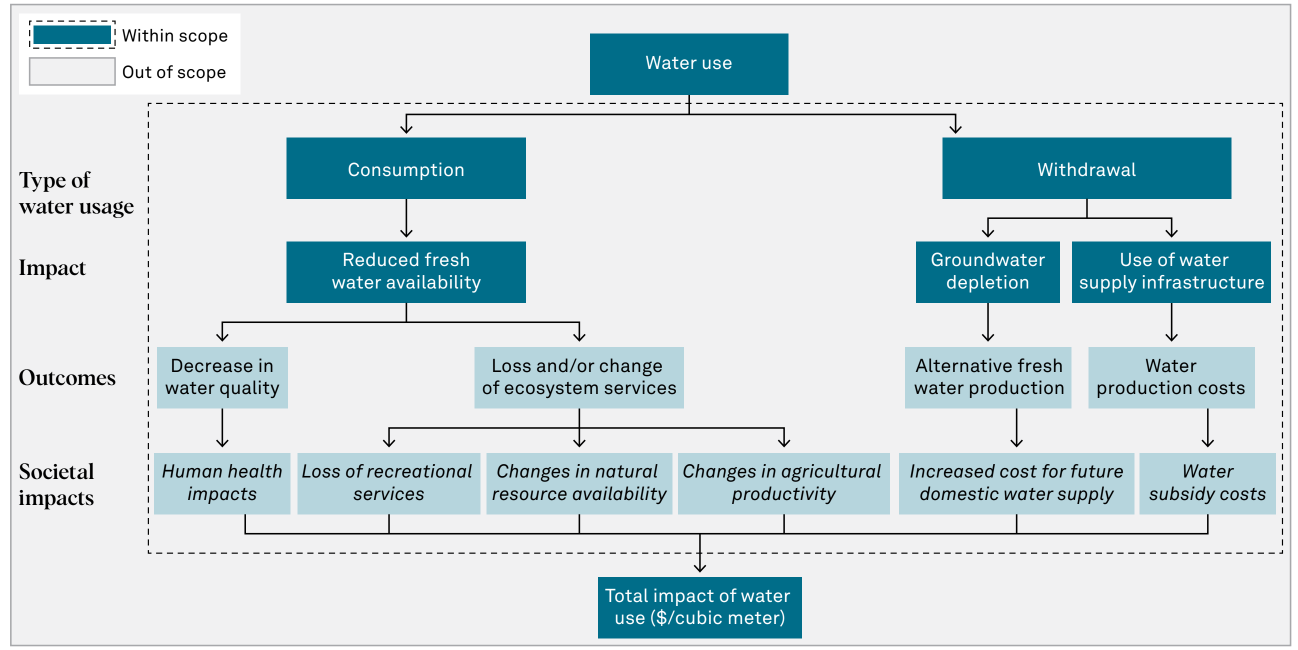
- The cost of water subsidy was estimated as the difference between the price of water in each country and the financial cost of water supply. As outlined by the World Bank (2005), subsidies engender distortions in the market price, thereby leading to an inefficient use of resources and indirectly raising the costs of service provision.

The water consumption valuation coefficients additionally reflect the impacts of reduced freshwater availability on terrestrial ecosystems and human health (Pfister, Koehler & Hellweg, 2009[84]; Motoshita et al., 2011[85]).

- Impacts of water consumption on ecosystem quality were measured in terms of the impact of consumptive water use on Net Primary Productivity (NPP). NPP is the rate at which plants store energy as food matter (FAO, 1987[86]) and it can be expressed as biomass per unit area. NPP was used as a proxy for ecosystem quality, as it is closely related to the vulnerability of vascular plant species biodiversity (Pfister, Koehler & Hellweg, 2009). The impacts of water consumption on NPP were then translated into potentially disappeared (i.e., lost) terrestrial ESV with respect to the average ESV in a given region, and monetized following a similar approach to the land use methodology in section 10.2.1.5.

- The impacts on human health due to waterborne diseases were quantified based on factors provided by Motoshita et al. (2011), describing human health impact in DALYs per cubic meter. The values are country-specific and estimate the impacts of ascariasis, trichiniasis, hookworm and diarrhea driven by consumptive water use. The impacts due to malnutrition were quantified based on the calculations outlined in Pfister et al. (2009). The DALY value was applied to the human health characterization factor and a monetary value was derived which highlights the human health impacts due to water consumption (see section 10.2.1.4).

Figure 6: Overview of S&P Global Sustainable1 impact pathway for water use



As of June 2024.
Source: S&P Global Sustainable1.

10.2.1.7 Natural Capital Impacts: Waste

Solid waste generation and disposal degrades the environment, indirectly impacting human wellbeing, and leading to external costs on society. As the waste impact pathway is complex and contains multiple levels, only the material issues identified have been addressed in this methodology.

The methodology considers the impacts of hazardous, non-hazardous and nuclear waste, and their respective contributions to climate change, air and water quality degradation, environmental disamenity, and harm to human health, as well as the extent to which these contributions vary according to the waste disposal method.

- The IPCC guidelines were followed to estimate the methane and carbon dioxide emissions from landfill and incineration, the appropriate GHG social damage costs were then applied to the quantified emissions (see section 10.2.1.3). Estimated avoided CO_2 emissions from the electricity grid were netted off in the case of disposal through incineration, as a result of the electricity generated during the waste incineration process.

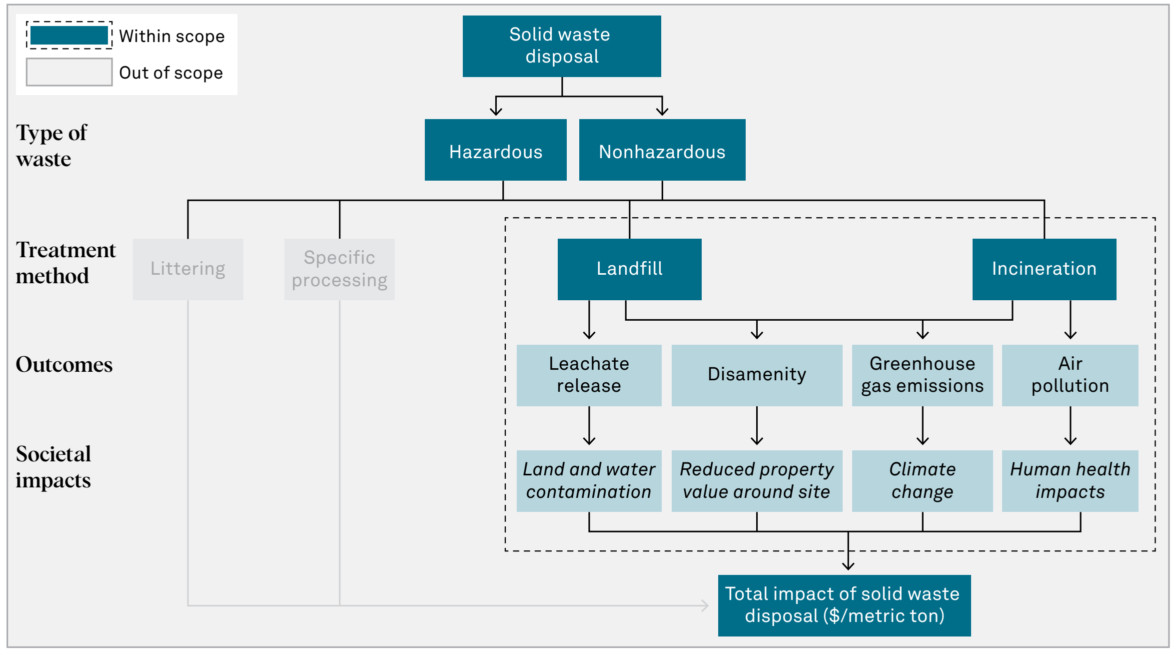
- The valuation of air pollutants released during the incineration of hazardous and non-hazardous waste was treated distinctly. Air pollutant factors for municipal solid waste were used as a proxy for non-hazardous (industrial) waste, and factors for a typical modern industrial waste incineration plant were used for the hazardous waste. Appropriate social damage costs for air pollutants (see section 10.2.1.4) were then applied to the quantified emissions.

- Common nuisances of waste disposal sites include noise, dust, litter, odor, the presence of vermin, traffic, visual intrusion, and enhanced perceptions of risk. These disamenity impacts were quantified similarly for disposal via landfill and incineration, using a meta-analysis of different studies based on the effect of the site on local house prices (i.e., a hedonic pricing method).

- Finally, the environmental outcomes associated with landfill leachate were quantified using a meta-analysis of selected national studies which value leachate release using the clean-up costs of the landfill facility (BDA, 2009[87]; Covec, 2007[88]).

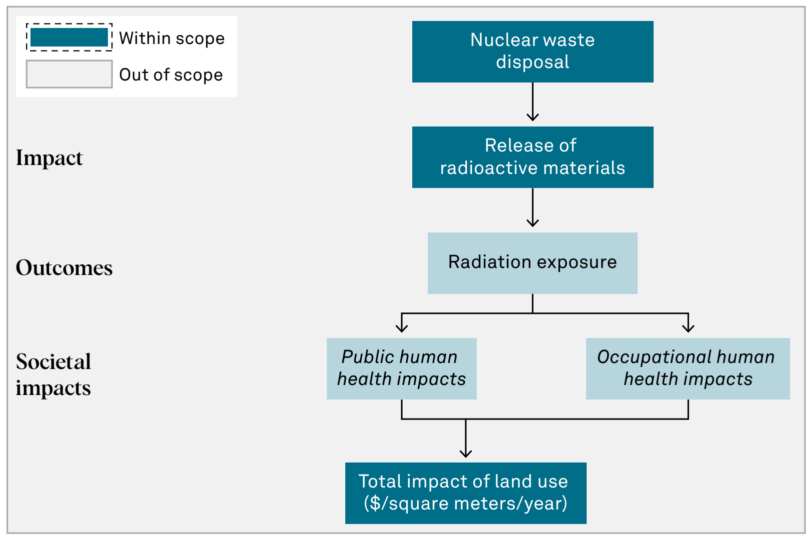
- Separately, the environmental and social damages caused by nuclear waste were estimated based on a study of external costs in the nuclear fuel cycle.

Figure 7: Overview of S&P Global Sustainable1 impact pathway for solid waste disposal



As of June 2024.
Source: S&P Global Sustainable1.

Figure 8: Overview of S&P Global Sustainable1 impact pathway for nuclear waste disposal



As of June 2024.
Source: S&P Global Sustainable1.

10.2.1.8 Natural Capital Impacts: Main Assumptions and Limitations

This report aims to assess the damage costs associated with a broad range of environmental impacts, at country level, across all major sectors in the global economy. Our approach does not consider more granular, localized characteristics associated with specific cities or point-location coordinates, which would have certain demographics, and geographical conditions. Instead, this report provides an overall view of the damage across regions and EKPIs, which therefore leads to some inherent uncertainty at the local level. A sensitivity analysis was performed, identifying the parameters with the greatest influence on the results while acknowledging the uncertainties associated with them. A summary of the main assumptions, and parameters evaluated, under each EKPI methodology can be found in Table 4.

Moreover, the methodology underlying each EKPI is based on an extended amount of research and academic studies, which each have their own scopes and limitations. A summary of these limitations can be found below:

10.2.1.8.1 Greenhouse Gases Limitations

Despite being the most complete measure of the damage caused by GHG emissions, SCC estimates have attracted much criticism as they omit or poorly quantify some major risks associated with climate change. This includes social unrest and disruptions to economic growth; ocean acidification; biodiversity, habitat and species extinction; and damages from most large-scale earth system feedback effects such as Arctic Sea ice loss and changing ocean circulation patterns (Howard, 2014[89]).

10.2.1.8.2 Air Land and Water Pollution Limitations

All impacts are assumed to occur in the year in which the pollutant was emitted, consistent with a steady-state scenario, whereby a company is assumed to discharge pollutants into the environment at a constant rate. An alternative approach might be to calculate the discounted sum of all human health and ecotoxicity impacts associated with the pollutants emitted in the year over all future years. However, it is not typically possible to isolate impact characterization data for individual years.

Table 4: Main assumptions under each EKPI methodology

EKPIs	Main assumptions/parameters
All	Income elasticity of environmental impacts
Greenhouse gases	Social discount rate
Air pollutants	Value of a DALY Air pollutant dispersion patterns and population exposed Value of ecosystem services lost
Land and water pollutants	Value of a DALY Land and water pollutant dispersion patterns and population exposed Steady-state scenario Value of ecosystem services lost
Land use	Baseline terrestrial ecoregions/biome type distribution by country Value of ecosystem services lost
Water use	Groundwater depletion rates by country Industrial water subsidy rates by country Social discount rate Value of a DALY Value of ecosystem services lost
Waste	Waste degradation rates Waste to energy recovery rate Social discount rate

As of June 2024.
EKPI = Environmental key performance indicator.
DALY = Disability-adjusted life year.
Source: S&P Global Sustainable1.

The ecotoxicity impacts only take into account one measure of biodiversity, and the valuation is not linked to a particular ecosystem service, but to total provisioning, regulating and cultural services, through one single measure of ecosystem functioning, net primary production. Irreversible damage has also not been included.

When considering the impacts of air pollutant emissions from companies operating in the water and air transportation sectors, it is important to note that emissions that occur far out at sea, or at high altitudes, and distant from densely populated areas, would result in less harm to human health. S&P Global Sustainable1 therefore adjusts the valuation coefficients of air pollutants by a scaling factor if they are generated from companies in the water and/or air transportation sector.

10.2.1.8.3 Waste Limitations

The scope of the S&P Global Sustainable1 methodology is to provide general impact values for solid waste disposal, depending on the type of waste treated (hazardous vs non-hazardous), the type of disposal, and the country-level location of the disposal site. Site-specific waste management practices and waste compositions were not taken into account in this report. Default coefficients were used for mixed industrial waste and no differentiation was made for plastic, organic, or textile waste, for example.

Due to limited data availability, the methodology in this report does not consider location-specific practices at individual sites, or the risk of major nuclear accidents. The latter are considered as unpredictable, black swan events that do not form part of a company's typical annual footprint.

10.2.1.8.4 Land Use Limitations

There is not a complete coverage of ecosystem services for each of the ecosystems. On the whole, ecosystem services are only valued where one or more primary valuation study has been published for that ecosystem. Where no monetary valuation exists for a particular ecosystem or service, the ecosystem or service has been estimated or excluded from this methodology.

The ecosystem (Olson, et al., 2004) and valuation datasets (De Groot, et al., 2012) do not provide enough granularity to obtain a focused analysis in specific geographical locations. For example, it is assumed that ecosystems such as tropical rainforest provide the same ecosystem services wherever they exist around the world.

The methodology does not take into account the change in quantity or quality of the same ecosystem services in different locations, and the values reflected may be subject to an upward or downward bias. The S&P Global Sustainable1 methodology is designed to reflect typical variation in the extent of ecosystem service loss that may be driven by land occupation for different purposes.

10.2.1.8.5 Water Use Limitations

The water use methodology contains several limitations due to the high uncertainty surrounding groundwater depletion rates and differences in water pricing methods. Moreover, the impacts on recreational activities were not considered in this methodology.

Groundwater depletion rates are highly variable and highly uncertain, as noted by Richey et al. (2015). The ecosystem damage highlighted in this methodology is limited to terrestrial ecosystems only. Aquatic ecosystems are excluded from the scope, even though aquatic organisms could also be affected by water consumption. In addition, a more robust and comprehensive method to quantify ecosystem quality could be developed in the future, extending beyond NPP, which is ultimately related to vascular plants.

10.2.2 Human and Social Impacts

The above natural capital cost analysis has been complemented by human and social capital data gathered via the S&P Global Corporate Sustainability Assessment (CSA), an annual evaluation of companies' sustainability practices.

The starting point for the annual corporate assessment is an industry-specific questionnaire that assesses, on average, 23 sustainability topics across 110 questions, focusing on relevant economic, environmental, and social criteria. Attention is centered on sustainability actions that can have an impact on companies' long-term value creation. For each of the 62 industries evaluated through the CSA, analysts conduct a materiality analysis to identify those sustainability factors that drive social and environmental impact as well as business value.

Based on major global sustainability challenges identified by analysts in S&P Global Sustainability Research Team, general criteria relating to standard management practices and performance measures such as Corporate Governance, Human Capital Development and Risk and Crisis Management are applied across each of the 62 industries, with these questions constituting up to 50% of the questionnaire. The remaining part of the CSA is made up of industry-specific risks and opportunities that focus on economic, environmental and social challenges and trends that are specifically relevant to companies within that industry.

For the analysis contained in this report, constituents of the S&P Global BMI were used as the company starting universe. CSA data was available for approximately 10,500 companies within this universe. However, as some datapoints were industry specific, the same datapoints were not available for all companies, and the sample size of companies considered has been included for each analysis.

More information on the CSA Methodology can be accessed here.

10.2.3 Nature Risk Methodology

Analysis of the nature dependency risks facing the sector groups in this report is based on the S&P Global Sustainable1 Nature & Biodiversity Risk Dataset, which applies the Nature Risk Profile Methodology for analyzing companies' impacts and dependencies on nature launched by S&P Global Sustainable1 and the UN Environment Programme in January 2023.

A business' dependency on ecosystem services is scored by combining the materiality of the dependency, the relevance of the services based on the locations operated in, and the resilience of the ecosystems providing those services. Materiality ratings are taken from the ENCORE knowledge base (Natural Capital Finance Alliance, 2022)[90], which assesses the links between each sector of the global economy, the ecosystem services that support their production processes, and the natural capital assets that support those services. Geospatial data on ecosystem services' relevance and resilience are then combined with the materiality ratings to assess dependency on each ecosystem service. These ecosystem service dependency scores are then aggregated to obtain an overall nature dependency score for a company.

The nature dependency scores are ranked on a scale ranging from 0 to 1, with a score of 0.2 indicating a very low dependency, while a score of 0.8 indicates a high level of dependency.

The full S&P Global Sustainable1 Nature & Biodiversity Risk Dataset methodology can be accessed here.

Table 5: Ecosystem service dependency scores under the nature risk profile methodology

Level of material dependency	Score
No dependency	0
Very low	0 to 0.2
Low	0.2 to 0.4
Moderate	0.4 to 0.6
High	0.6 to 0.8
Very high	0.8 to 1

As of June 2024.
Source: S&P Global Sustainable1.

11. Sources

1 United Nations Environment Programme. 2023. “Nature Risk Profile: A methodology for profiling nature related dependencies and impacts.” https://www.spglobal.com/esg/solutions/nature-risk-profile-methodology.pdf

2 S&P Global Sustainable1. 2022. “Biodiversity is still a blind spot for most companies around the world.” https://www.spglobal.com/esg/insights/biodiversity-is-still-a-blind-spot-for-most-companies-around-the-world

3 World Economic Forum. 2020. “The Future Of Nature And Business.” https://www3.weforum.org/docs/WEF_The_Future_Of_Nature_And_Business_2020.pdf

4 PwC. 2023. “PwC boosts global nature and biodiversity capabilities with new Centre for Nature Positive Business, as new research finds 55% of the world’s GDP - equivalent to $58 trillion - is exposed to material nature risk without immediate action.” https://www.newswire.ca/news-releases/pwc-boosts-global-nature-and-biodiversity-capabilities-with-new-centre-for-nature-positive-business-as-new-research-finds-55-of-the-world-s-gdp-equivalent-to-58-trillion-is-exposed-to-material-nature-risk-without-immediate-action-878247053.html

5 S&P Global Sustainable1. 2023. “How the world’s largest companies depend on nature and biodiversity.” https://www.spglobal.com/esg/insights/featured/special-editorial/how-the-world-s-largest-companies-depend-on-nature-and-biodiversity

6 S&P Global Sustainable1. 2022. “Rocks and hard places: The complicated nexus of energy transition minerals and biodiversity.” https://www.spglobal.com/esg/insights/featured/special-editorial/rocks-and-hard-places-the-complicated-nexus-of-energy-transition-minerals-and-biodiversity

7 World Health Organization. 2022. “Ambient (outdoor) air pollution.” https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

8 World Bank. 2022. “The Global Health Cost of PM2.5 Air Pollution: A Case for Action Beyond 2021.” https://elibrary.worldbank.org/doi/epdf/10.1596/978-1-4648-1816-5

9 Earth Overshoot Day. Global Footprint Network. https://overshoot.footprintnetwork.org/about/

10 S&P Global Sustainable1. 2022. “What companies and investors need to know from the IPCC’s climate adaptation report.” https://www.spglobal.com/esg/insights/what-companies-and-investors-need-to-know-from-the-ipcc-s-climate-adaptation-report

11 International Financial Reporting Standards Foundation. 2023. “ISSB issues inaugural global sustainability disclosure standards.” https://www.ifrs.org/news-and-events/news/2023/06/issb-issues-ifrs-s1-ifrs-s2/

12 IFRS Foundation. April 2024. “ISSB to commence research projects about risks and opportunities related to nature and human capital.” https://www.ifrs.org/news-and-events/news/2024/04/issb-commence-research-projects-risks-opportunities-nature-human-capital/

13 European Commission. 2023. “The Commission adopts the European Sustainability Reporting Standards.” https://finance.ec.europa.eu/news/commission-adopts-european-sustainability-reporting-standards-2023-07-31_en

14 The Stock Exchange of Hong Kong Limited. 2023. “Exchange Publishes Consultation Paper on Enhancement of Climate Disclosure under its ESG Framework.” https://www.hkex.com.hk/News/Regulatory-Announcements/2023/230414news?sc_lang=en

15 S&P Global Sustainable1. March 2024. “After SEC rulemaking, assessing the US climate disclosure landscape.” https://www.spglobal.com/esg/insights/featured/special-editorial/after-sec-rulemaking-assessing-the-us-climate-disclosure-landscape

16 US Securities and Exchange Commission. ”In the Matter of the Enhancement and Standardization of Climate-Related Disclosures for Investors (Order Issuing Stay).” April 4, 2024. https://www.sec.gov/files/rules/other/2024/33-11280.pdf

17 European Commission. 2023. “Commission adopts detailed reporting rules for the Carbon Border Adjustment Mechanism’s transitional phase.” https://ec.europa.eu/commission/presscorner/detail/en/ip_23_4186

18 UN Convention on Biological Diversity. 2022. “Nations Adopt Four Goals, 23 Targets for 2030 In Landmark UN Biodiversity Agreement.” https://www.cbd.int/article/cop15-cbd-press-release-final-19dec2022

19 Taskforce on Nature-related Financial Disclosures. 2023. “Final TNFD Recommendations on nature related issues published and corporates and financial institutions begin adopting.” https://tnfd.global/final-tnfd-recommendations-on-nature-related-issues-published-andcorporates-and-financial-institutions-begin-adopting/

20 US Environmental Protection Agency. 2016. “EPA Fact Sheet: Social Cost of Carbon.” https://www.epa.gov/sites/default/files/2016-12/documents/social_cost_of_carbon_fact_sheet.pdf

21 Sources of Greenhouse Gas Emissions. 2023. US Environmental Protection Agency. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#electricity

22 Water and agriculture . Page accessed Oct. 13, 2023. OECD. https://www.oecd.org/agriculture/topics/water-and-agriculture/

23 Clean Water Act: EPA Should Track Control of Combined Sewer Overflows and Water Quality Improvements. 2023. US Government Accountability Office. https://www.gao.gov/products/gao-23-105285

24 Combined Sewer Overflows (CSOs). Page updated Oct 5, 2023. US EPA. https://www.epa.gov/npdes/combined-sewer-overflows-csos

25 Effects of Water Pollution on Human Health and Disease Heterogeneity: A Review. 2022. Frontiers in Environmental Science. https://www.frontiersin.org/articles/10.3389/fenvs.2022.880246/full

26 Status and Trends in Spent Fuel and Radioactive Waste Management. 2022. International Atomic Energy Agency. https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1963_web.pdf

27 US Energy Information Administration. “Coal and the environment.” https://www.eia.gov/energyexplained/coal/coal-and-the-environment.php

28 European Environmental Bureau. 2017. “New rules hasten end for Europe’s dirtiest power plants.” https://eeb.org/new-rules-hasten-end-for-europes-dirtiest-power-plants/

29 Economic Research Institute for ASEAN and East Asia. 2017. “Improving Emission Regulation for Coal-fired Power Plants in ASEAN.” https://www.eria.org/RPR_FY2016_02.pdf

30 International Energy Agency. 2022. “Global Hydrogen Review 2022.” https://www.iea.org/reports/global-hydrogen-review-2022/executive-summary

31 International Energy Agency. “Carbon Capture, Utilisation and Storage.” https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage

32 Investor Alliance for Human Rights. https://investorsforhumanrights.org/about

33 United Nations Environment Programme Finance Initiative. 2014. “General manufacturing.” https://www.unepfi.org/humanrightstoolkit/manufacturing.php

34 International Energy Agency. 2023. “Methane emissions remained stubbornly high in 2022 even as soaring energy prices made actions to reduce them cheaper than ever.” https://www.iea.org/news/methane-emissions-remained-stubbornly-high-in-2022-even-as-soaring-energy-prices-made-actions-to-reduce-them-cheaper-than-ever

35 US Environmental Protection Agency. “Importance of methane.” https://www.epa.gov/gmi/importance-methane#:~:text=Methane%20is%20also%20a%20greenhouse,%2Dinfluenced)%20and%20natural%20sources.

36 International Energy Agency. 2022. “Methane and climate change.” https://www.iea.org/reports/global-methane-tracker-2022/methane-and-climate-change

37 Sonter, Laura J., Ali, Saleem H. and Watson, James E. M. 2018. “Mining and biodiversity: key issues and research needs in conservation science.” https://royalsocietypublishing.org/doi/10.1098/rspb.2018.1926

38 McClung, Maureen R. and Moran, Matthew D. 2018. “Understanding and mitigating impacts of unconventional oil and gas development on land-use and ecosystem services in the U.S.” https://www.hendrix.edu/uploadedFiles/General_Content/Employee_Profiles/Faculty/Biology/McclungandMoran2018.pdf

39 Johnston JE, Lim E, Roh H. 2019. “Impact of upstream oil extraction and environmental public health: A review of the evidence.” Sci Total Environ. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6344296/

40 US Geological Survey Water Resources Mission Area. 2019. “Hydraulic fracturing.” https://www.usgs.gov/mission-areas/water-resources/science/hydraulic-fracturing

41 Caldwell, Jennifer A., Christopher K. Williams, Margaret C. Brittingham, and Thomas J. Maier. 2022. “A Consideration of Wildlife in the Benefit-Costs of Hydraulic Fracturing: Expanding to an E3 Analysis” Sustainability 14, no. 8: 4811. https://doi.org/10.3390/su14084811

42 US Environmental Protection Agency. 2015. “Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources.” https://www.epa.gov/sites/default/files/2015-07/documents/hf_es_erd_jun2015.pdf

43 Elaine L. Hill and Lala Ma. 2022. “Drinking water, fracking, and infant health.” Journal of Health Economics Volume 82. https://www.sciencedirect.com/science/article/abs/pii/S0167629622000157?via%3Dihub

44 Johnston JE, Lim E, Roh H. 2019. “Impact of upstream oil extraction and environmental public health: A review of the evidence.” Sci Total Environ. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6344296/

45 McClung, Maureen R. and Moran, Matthew D. 2018. “Understanding and mitigating impacts of unconventional oil and gas development on land-use and ecosystem services in the U.S.” https://www.hendrix.edu/uploadedFiles/General_Content/Employee_Profiles/Faculty/Biology/McclungandMoran2018.pdf

46 S&P Global Market Intelligence. “Battery Metals Market.” https://www.spglobal.com/marketintelligence/en/campaigns/battery-metals-market

47 S&P Global Sustainable1. 2022. “Rocks and hard places: The complicated nexus of energy transition minerals and biodiversity.” https://www.spglobal.com/esg/insights/featured/special-editorial/rocks-and-hard-places-the-complicated-nexus-of-energy-transition-minerals-and-biodiversity

Sources

48 Dialogo Chino. 2022. “Mexican communities fight fracking as projects hit indigenous areas.” https://dialogochino.net/en/climate-energy/58063-fracking-mexican-communities-fight-back-as-projects-fracture-indigenous-areas/

49 Allard C, Curran D. “Indigenous Influence and Engagement in Mining Permitting in British Columbia, Canada: Lessons for Sweden and Norway?” Environ Manage. 2023 Jul;72(1):1-18. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10220105/

50 World Bank. 2017. “ESS5: Land Acquisition, Restrictions on Land Use and Involuntary Resettlement.” https://thedocs.worldbank.org/en/doc/796881511809516397-0290022017/original/EnvironmentalSocialStandardESS5FactSheetWBESF.pdf

51 Science Direct. “Bunker (fuel).” https://www.sciencedirect.com/topics/earth-and-planetary-sciences/bunker-fuel

52 S&P Global Sustainable1. 2021. “Your climate change goals may have a maritime shipping problem.” https://www.spglobal.com/esg/insights/your-climate-change-goals-may-have-a-maritime-shipping-problem

53 S&P Global Commodity Insights. 2023. “IMO agrees net-zero goal, confirms GHG pricing and new fuel rules development.” https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/shipping/070723-imo-agrees-net-zero-goal-confirms-ghg-pricing-and-new-fuel-rules-development#:~:text=Following%20a%20week%20of%20discussions,on%20a%20life%2Dcycle%20basis.

54 International Air Transport Association. ” Net zero 2050: sustainable aviation fuels.” https://www.iata.org/en/iata-repository/pressroom/fact-sheets/fact-sheet---alternative-fuels/

55 European Commission. “Social issues, Equality and attractiveness of the transport sector.” https://transport.ec.europa.eu/transport-themes/social-issues-equality-and-attractiveness-transport-sector_en

56 US Geological Survey. 2019. “Agricultural Contaminants.” https://www.usgs.gov/mission-areas/water-resources/science/agricultural-contaminants#:~:text=Agricultural%20contaminants%20can%20impair%20the,streams%2C%20rives%2C%20and%20groundwater.

57 Meijaard, E., Brooks, T.M., Carlson, K.M. et al. “The environmental impacts of palm oil in context.” Nat. Plants 6, 1418–1426 (2020). https://doi.org/10.1038/s41477-020-00813-w

58 Ammonia emissions from agriculture and their contribution to fine particulate matter: A review of implications for human health. 2022. Journal of Environmental Management. https://www.sciencedirect.com/science/article/pii/S0301479722018588

59 A methodology for estimating the ammonia emission from crop residues at a national scale. 2019. Atmospheric Environment. https://www.sciencedirect.com/science/article/pii/S2590162119300310

60 Seed Yield and Nitrogen Efficiency in Oilseed Rape After Ammonium Nitrate or Urea Fertilization. 2021. Frontiers in Plant Science.
https://www.frontiersin.org/articles/10.3389/fpls.2020.608785/full

61 Pollination, Seed Predation and Seed Dispersal. Advances in Ecological Research (Fifth edition) 2022 https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/pollinator-decline

62 Worldwide occurrence records suggest a global decline in bee species richness. 2021. One Earth. https://www.cell.com/one-earth/fulltext/S2590-3322(20)30651-5

63 Climate Change 2022: Impacts, Adaptation and Vulnerability. Intergovernmental Panel on Climate Change (Box 5.3: Pollinators). 2022. https://report.ipcc.ch/ar6/wg2/IPCC_AR6_WGII_FullReport.pdf

64 Stockholm Environment Institute. ”Trase: Brazilian beef exports and deforestation.” Nov. 21, 2023. https://www.sei.org/

features/trase-brazil-beef-exports-deforestation/#:~:text=In%20Brazil%2C%20beef%20exports%20in,annual%20emissions%20%EF%BB%BF%20in%202020.

65 FAO and UNEP. 2020. The State of the World's Forests 2020. Forests, biodiversity and people. Rome. https://doi.org/10.4060/ca8642en

66 FAO and UNEP. 2020. The State of the World's Forests 2020. Forests, biodiversity and people. Rome. https://doi.org/10.4060/ca8642en

67 UN Environment Programme. 2021. "Methane emissions are driving climate change. Here's how to reduce them." https://www.unep.org/news-and-stories/story/methane-emissions-are-driving-climate-change-heres-how-reduce-them

68 Keeler, B. L., Polasky, S., Brauman, K. A., A., J. K., Finlay, J. C., O'Neill, A., & ... Dalzell, B. (2012). Linking water quality and well-being for improved assessment and valuation of ecosystem services. Proceedings of the National Academy of Sciences, 109(45), 18619-18624.

69 More information on S&P Global Sustainable1's EEIO Model can be accessed here.

70 IPCC. (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. Averyt, . . . H. Miller, Eds.) Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

71 IPCC. (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. (T. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. Allen, J. Boschung, . . . P. Midgley, Eds.) Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

72 IPCC. (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. doi:10.1017/9781009157896

73 Interagency Working Group on Social Cost of Greenhouse Gases. (2016). Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis - Under Executive Order 12866. United States Government. Retrieved from https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf

74 WHO. (2020). WHO methods and data sources for global burden of disease estimates 2000-2019. Geneva: World Health Organization. Retrieved from https://cdn.who.int/media/docs/default-source/gho-documents/global-health-estimates/ghe2019_daly-methods.pdf?sfvrsn=31b25009_7

75 MA. (2005). Millenium Ecosystem Assessment. Ecosystems and Human Well-being: Synthesis. Washington, DC: Island Press.

76 De Groot, R., Brander, L., Ploeg, V. D., S., C. R., Bernard, F., Braat, L., . . . Van Beukering, P. (2012). Global estimates of the value of ecosystems and their services in monetary units. Ecosystem services, 1(1), 50-61.

77 European Environment Agency. (1997). Water Stress in Europe: Can the Challenge be Met? EEA and UNEP. Retrieved from https://www.eea.europa.eu/publications/92-9167-025-1/page003.html

78 GWI. (2019). The Global Water Tariff Survey. Retrieved from https://www.globalwaterintel.com/products-and-services/market-research-reports/tariff-survey

79 FAO. (2022). AQUASTAT Database. Retrieved from http://www.fao.org/nr/water/aquastat/data

80 Zhou, Y., & Tol, R. S. (2005). Evaluating the costs of desalination and water transport. Water Resour. Res., 41, W03003. doi:10.1029/2004WR003749.

81 Richey, A. S., Thomas, B. F., Lo, M., Famiglietti, J. S., Swenson, S., & Rodell, M. (2015). Uncertainty in global groundwater storage estimates in a total groundwater stress framework. Water Resources Research, 51. [Online]. Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015WR017351, 5198-5216.

82 Gassert, F., Reig, P., Luo, T., & Maddocks., A. (2013). Aqueduct country and river basin rankings: a weighted aggregation of spatially distinct hydrological indicators, Working paper. Washington, DC: World Resources Institute. Retrieved from http://wri.org/publication/aqueduct-country-river-basin-rankings.

83 Abdullah, R., Foster, V., Halpern, J. D., Komives, K., & Wodon, Q. T. (2005). Water, Electricity, and the Poor: Who Benefits from Utility Subsidies? Washington, D.C.: Directions in development, World Bank Group. Retrieved from http://documents.worldbank.org/curated/en/606521468136796984/Water-electricity-and-the-poor-who-benefits-from-utility-subsidies

84 Pfister, S., Koehler, A., & Hellweg, S. (2009). Assessing the Environmental Impacts of Freshwater Consumption in LCA. Environmental Science & Technology, 43(11), 4098-4104.

85 Motoshita, M., Itsubo, N., & Inaba, A. (2011). Development of impact factors on damage to health by infectious diseases caused by domestic water scarcity. The International Journal of Life Cycle Assessment, 16, 65-73.

86 FAO. (1987). Site Selection For Aquaculture: biological productivity of water bodies. United Nations Development Programme, Food and Agriculture Organization of the United Nations.

87 BDA Group (2009) The full cost of landfill disposal in Australia. Prepared for DEWHA, 13 July

88 Covec (2007) Recycling: Cost Benefit Analysis. Prepared for Ministry for the Environment, NZ.

89 Howard, P. (2014). Omitted Damages: What's Missing From the Social Cost of Carbon. The Cost of Carbon Project, a joint project of the Environmental Defense Fund, the Institute for Policy Integrity, and the Natural Resources Defense Council.

90 Natural Capital Finance Alliance (Global Canopy, UNEP FI, and UNEP-WCMC) (2022). ENCORE: Exploring Natural Capital Opportunities, Risks and Exposure. [On-line], Cambridge, UK: the Natural Capital Finance Alliance. Available at: https://encore.naturalcapital.finance. DOI: https://doi.org/10.34892/dz3x-y059.