In collaboration with Accenture

Net-Zero Industry Tracker

2023 Edition

KEY TAKEAWAYS

Foreword

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In a decade marked by economic expansion and surging demand for goods and transport, we face a paradoxical challenge: How can we address climate change while fostering economic growth and resilience? This challenge is particularly difficult for companies operating in the steel, cement, aluminium, ammonia, energy and transport sectors. These companies are critical to satisfying future demand and enabling economic growth. Yet, they contribute over 40% of the world's greenhouse gas (GHG) emissions. Their emissions are difficult, but critical to abate.

It is encouraging that many businesses have made significant progress towards their 2050 net-zero goals. Yet most of that momentum is seen in companies with easily abatable emissions, substantial financial resources to invest in decarbonization, public accountability or those operating in advanced economies with supportive policies. A gap remains between those abatement leaders and companies experiencing greater emission intensity, operating in emerging economies or lacking the financial means to embark on a substantial decarbonization journey. The challenges facing these companies and sectors are pernicious – and exacerbated by the fact that their technologies, infrastructures and policy frameworks often fall short.

Through this effort, the World Economic Forum, with support from Accenture, intends to accelerate decarbonization of emission-intensive production, energy and transport industries. Our aim is to ensure that no company is left behind in the transition to a more sustainable and carbon-neutral future, for which timely and consistent monitoring of industrial decarbonization is essential. This practice is crucial to helping companies and industries maintain a steady pace of progress. Still, it first requires a consensus on definitions and thresholds of low-emission products and services from these sectors. Without that, it will be difficult to achieve the transparency needed to build confidence and reinforce the momentum to net zero.

The *Net-Zero Industry Tracker* focuses on production, transport and energy sectors. Decarbonizing these industries' processes and value chains will require more than technological advancements. The effort must encompass business operations, regulations and wider cross-sectoral collaboration. While some countries are issuing supportive policies and financial commitments, the reality is that these sectors are lagging.

We believe a course correction is still possible. It will require industrial leaders to champion innovative business models and shared infrastructures, such as hubs and clusters, that provide greater access to development opportunities and promote equitable sector growth. A successful transition will also require significant financial commitments; we estimate roughly $13.5 trillion will be needed to build the clean power and electrification, hydrogen and carbon capture utilization and storage (CCUS) solutions and infrastructure to meet demand. Bi-directional partnerships and cross-industry collaboration will also be important in stimulating demand for (and adoption of) low-emission products and clean power-based technologies, developing industrial applications and pursuing new market opportunities. Sector-specific policies and regulations are essential. So are cross-regional policies that can help bridge disparities among regions.

Industrial decarbonization remains one of the most daunting challenges of the energy transition. Every country and industry must determine how to incentivize domestic benefits and create quality jobs while ensuring the principles of free trade and open markets. The key findings from the 2023 Global Stocktake of the Paris Agreement confirm that reaching global net zero by 2050 requires much more ambitious actions and far greater support than we have seen. The reality is that the choices and actions taken in this decade will significantly shape the trajectory of our collective futures.

Executive summary

The World Economic Forum's *Net-Zero Industry Tracker 2023 Edition* provides a detailed analysis of the progress emission-intensive industrial sectors are making worldwide, in their efforts to achieve net-zero emissions by 2050. This analysis focuses on sector-specific accelerators and priorities in the harder-to-abate aspects within production (i.e. steel, cement, aluminium and ammonia), energy (i.e. oil and gas) and transport (i.e. aviation, shipping and trucking). Collectively, process- and energy-related emissions from these sectors account for more than 40% of global greenhouse gas (GHG) emissions, which is higher than the emissions of any individual country. For that reason, transparency on the progress these sectors are making is essential for timely and effective interventions to ensure we are on track for net-zero emissions by 2050.

While the pathway to net zero in industrial sectors will differ based on unique sectoral and regional factors, a blend of electrification (clean power), clean hydrogen and fossil fuels abated by carbon capture utilization and storage (CCUS) form the basis of industrial decarbonisation across most sectors. However, a robust enabling environment is necessary to allow them to achieve their respective decarbonization objectives. To help in this, the *Net-Zero Industry Tracker* applies a standardized conceptual framework, including emission drivers and enablers, that not only provides a collective measure of progress and gaps but also highlights opportunities for cross-sector collaboration.

The analysis shows that emission-intensive sectors are not aligned with the trajectory to reach net zero by 2050 – as determined by the International Energy Agency (IEA) and industry specific scenarios and targets. Over the past three years, absolute emissions have grown on average by 8% due to increased activity and demand and all sectors in scope depend on fossil fuels, most with over 90% reliance. Sectors such as cement and steel are facing the most complex decarbonization challenges due to their energy intensity. In fact, their use of energy is equivalent to more than 3 times that of the energy consumed in the US. Transitioning these industries to a net-zero future will require a collective investment of approximately $13.5 trillion, prioritizing the electrification of low to medium temperature industrial processes. That is what's needed to scale up the essential technologies and sustainable infrastructure, but investments aren't enough. They must be complemented by policies and incentives that can help the industries make the switch while ensuring access to affordable and reliable resources that are critical for economic growth.

The tracker reveals an encouraging, though variable, increase in awareness and action among industries towards achieving net-zero emissions. Yet, there is still tremendous opportunity for sectors to come together to drive innovation and address their challenges collaboratively through sharing knowledge and best practices, joint innovation, market access and consumer trust, risk mitigation and resiliency planning.

BOX 1

Definitions

Clean power: A combination of solar, off-shore wind, on-shore wind, nuclear and geothermal energy used to electrify thermal processes in production and as an alternative propulsion source in transport sectors.

Clean hydrogen: Considers both blue hydrogen (produced with natural gas abated by CCUS) and green hydrogen (produced through electrolysis). Though the preference in most cases is towards green hydrogen.

Green premium: Additional products/fuel costs passed to businesses and end consumers, associated with adoption of low-emission technologies.

TABLE 1 | **Five key takeaways from the 2023 tracker**

Technology	**The use of low-emission technologies is growing at a gradual pace; rapid acceleration is needed to support commercial deployment by 2030.** The readiness and adoption of low-emission technology remains low across most sectors. Aluminium and trucking are two sectors showing early promise. Prioritizing material circularity, recycling and transition fuels can help industries bridge the gap until technologies become available.
Infrastructure	**Financing needs for low-emission technologies are significant yet overshadowed by larger infrastructure investments.** Industries are largely reliant on clean hydrogen, CCUS and electrification including recharging infrastructure for transport sectors. While local characteristics like clean power and storage site proximity will drive early technology adoption, shared infrastructure hubs are vital to accelerated decarbonization and improved access in remote locations.
Demand	**Standardized definitions and thresholds for low-emission products are gaining consensus, essential for encouraging first movers.** Early market demand signals are emerging in most sectors. Over the last year, some production sectors have witnessed an increase in low-carbon alternatives. Yet challenges like reporting standards, supply chain instability and transparency gaps persist. In some instances, business to business (B2B) green premiums reaching up to 400%, are largely untested at scale. End-product consumers generally experience relatively modest green premiums, typically 2-5%.
Policy	**The evolving policy landscape, driven by significant industrial policy initiatives in select countries, is bolstering investment in low-emission technologies and infrastructure.** However, this shift may risk concentrating industrial activity in developed nations, necessitating multilateral cooperation to aid major producing regions. Global alignment on emissions reduction requirements is needed, with policies customized to suit individual country needs. Additionally, enhancing market transparency necessitates policy measures to increase emission intensity visibility.
Capital	**Sectors need additional investments of approximately $11 trillion to fund adoption of clean energy technologies and retrofit legacy assets, however most industries lack strong business cases.** Such a shift in capital flows should be supported by market stabilizing policies to enhance investment attractiveness and companies embedding long-term decarbonization solutions into their strategies to targeting growth through sustainable value creation. Capital is also needed to improve emission efficiencies for processes that cannot be fully electrified.

In conclusion, decarbonizing emission-intensive industries across production, energy and transport sectors requires a multi-faceted approach. Aligning the essential components of demand for sustainable products, policy incentives, capital for technology investments and infrastructure expansion is the key to accelerating progress. Positive signals are currently emerging, but much more needs to be done. Recognizing a new and evolving geopolitical context, a new equilibrium needs to be found on how collaboration across countries needs to happen to support this transition that should preserve the conditions for every living being and also create wealth. The 2023 tracker report recognizes that, despite the challenges, the global industrial community is making progress towards achieving net-zero emissions. By pulling the enabling levers and encouraging innovative collaborations, industries can pave the way for a greener, more resilient and prosperous future.

Introduction

The *Net-Zero Industry Tracker* offers a data-driven framework to assess and comprehend the progress of decarbonization across emissions-intensive industry sectors.

Its key objectives include supporting the global endeavour of industry net-zero transformation by providing stakeholders with a detailed framework and methodology to comprehend the driving forces behind industry emissions and the facilitators of net-zero transformation. Additionally, it provides both quantitative and qualitative scorecards to continually monitor industry advancements towards the net-zero goal. Moreover, it identifies priority areas for industries to focus on, promoting actions that accelerate their progress in the journey towards sustainability.

The underlying framework combines two complementary lenses to track industries' progress on the ground – performance and readiness. This year, to increase the overall volume of emissions being tracked, three transport sectors have been included. Consequently, the 2023 iteration of the framework for production and energy sectors remains the same, whereby the field of analysis covers scope 1 and 2 emissions. However, an adapted version has been developed to account for variance in reporting requirements for the newly incorporated transport sectors, which will account for greenhouse gas (GHG) emissions in the fuel supply and operational value chains (well-to-wake emissions) against 2050 targets.

BOX 2

Definitions

"Low-emission" production is defined quantitatively for each industry in terms of product emission intensity (scope 1 and 2).

Targets refer to 2030 and 2050 emission intensity thresholds based on sector net-zero trajectories used for the analysis. These are proposed trajectories based on analysis of data from the International Energy Agency (IEA) *Net Zero by 2050*, Global Cement and Concrete Association (GCCA) Concrete Future, International Air Transport Association (IATA) Net Zero Roadmaps, International Aluminium Institute (IAI) GHG Pathways, International Council on Clean Transportation (ICCT) Vision 2050 and International Maritime Organization (IMO) GHG Strategy. Business as usual (BAU) trajectories have also been considered based on the IEA Stated Policies Scenario and Mission Possible Partnership (MPP) sector trajectories. These trajectories are for this analysis only and not a final recommendation for the industries.

FIGURE 1 **Net-Zero Industry Tracker framework – performance**

Net-zero industry performance
The four drivers of industry net GHG emissions:

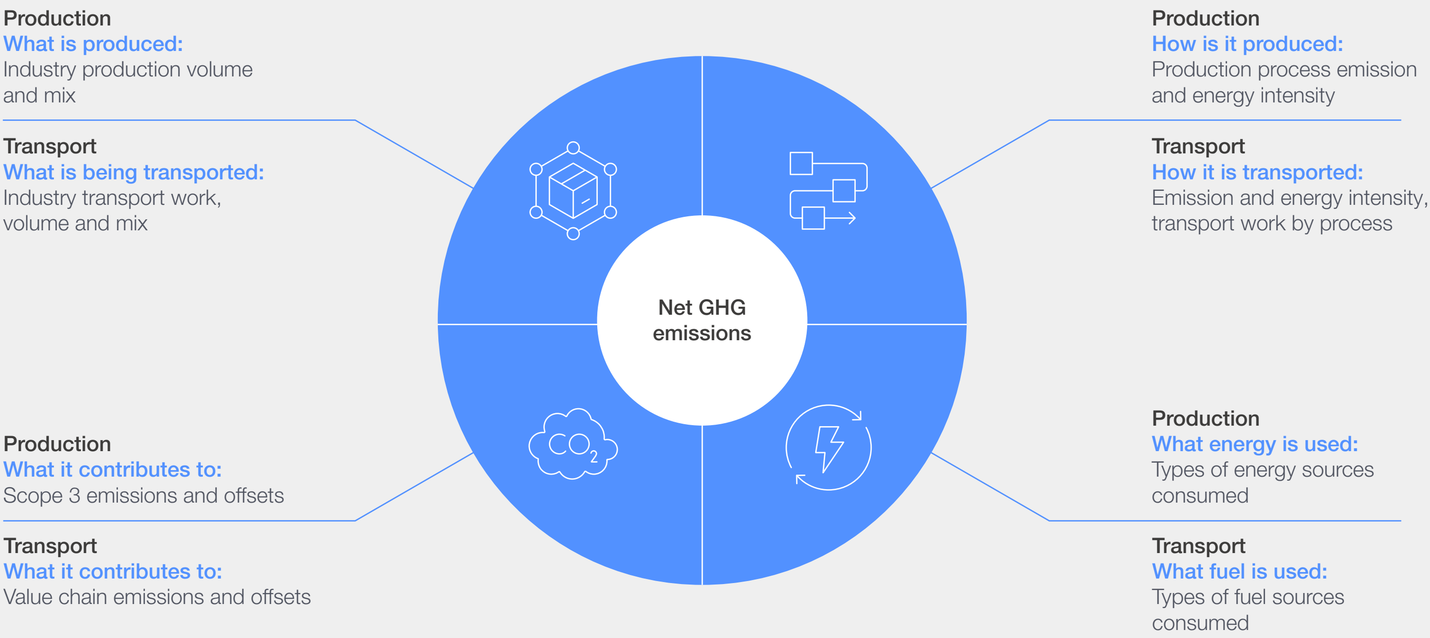
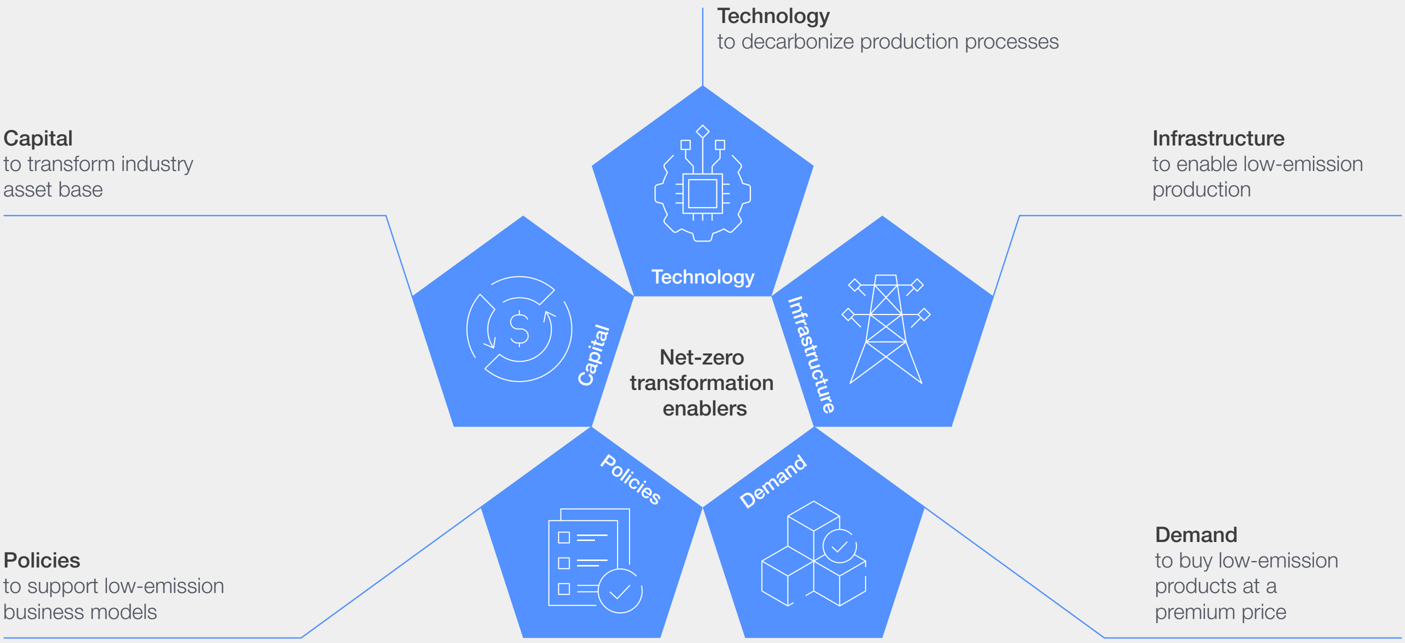


FIGURE 2 **Net-Zero Industry Tracker framework – readiness**

Net-zero industry readiness
The five enabling dimensions of industry net-zero transformation:



Each of the enablers is assessed against five stages of readiness, with the assessment criteria outlined in Appendix A2: Mission and methodology.

TABLE 2 | Scoring matrix for transformation enablers

Key readiness questions	**Technology** Is the technology to produce a low-emission product at competitive cost available?	**Infrastructure** Is the infrastructure to enable use of low-emission technologies available?	**Demand** Can the market pay the required green premium for the low-emission product?	**Policies** Are the supporting policies to enable the growth of low-emission industry in place?	**Capital** Are returns sufficient to drive investments towards low-emission assets?
Stage 5	The low-emission production technologies are **fully available and competitive with high-emission alternatives.**	The necessary infrastructure required by the low-emission industry **is fully in place.**	**The whole market** can pay the required green premium.	Policies **fully** complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for **all** capital expenditure (CapEx) to flow towards low-emission production assets.
Stage 4	The low-emission production technologies are **largely commercial and competitive with high-emission alternatives.**	The necessary infrastructure required by the low-emission industry is **largely in place.**	**Most of the market** can pay the required green premium.	Policies **strongly** complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for **most** CapEx to flow towards low-emission production assets.
Stage 3	The low-emission production technologies are **largely demonstrated in commercial conditions.**	The necessary infrastructure required by the low-emission industry is **partially in place.**	**Some of the market** can pay the required green premium.	Policies **moderately** complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for **some** of CapEx to flow towards low-emission production assets.
Stage 2	The low-emission production technologies are **largely prototyped at scale.**	The necessary infrastructure required by the low-emission industry **is emerging.**	**A limited portion** of the market can pay the required green premium.	**Limited** policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for a **minority** of CapEx to flow towards low-emission production assets.
Stage 1	The low-emission production technologies are **largely at concept or early prototype stage.**	The necessary infrastructure required by the low-emission industry **needs to be developed almost entirely.**	**Only very early adopters** in the market can pay the required green premium.	**Very limited** policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

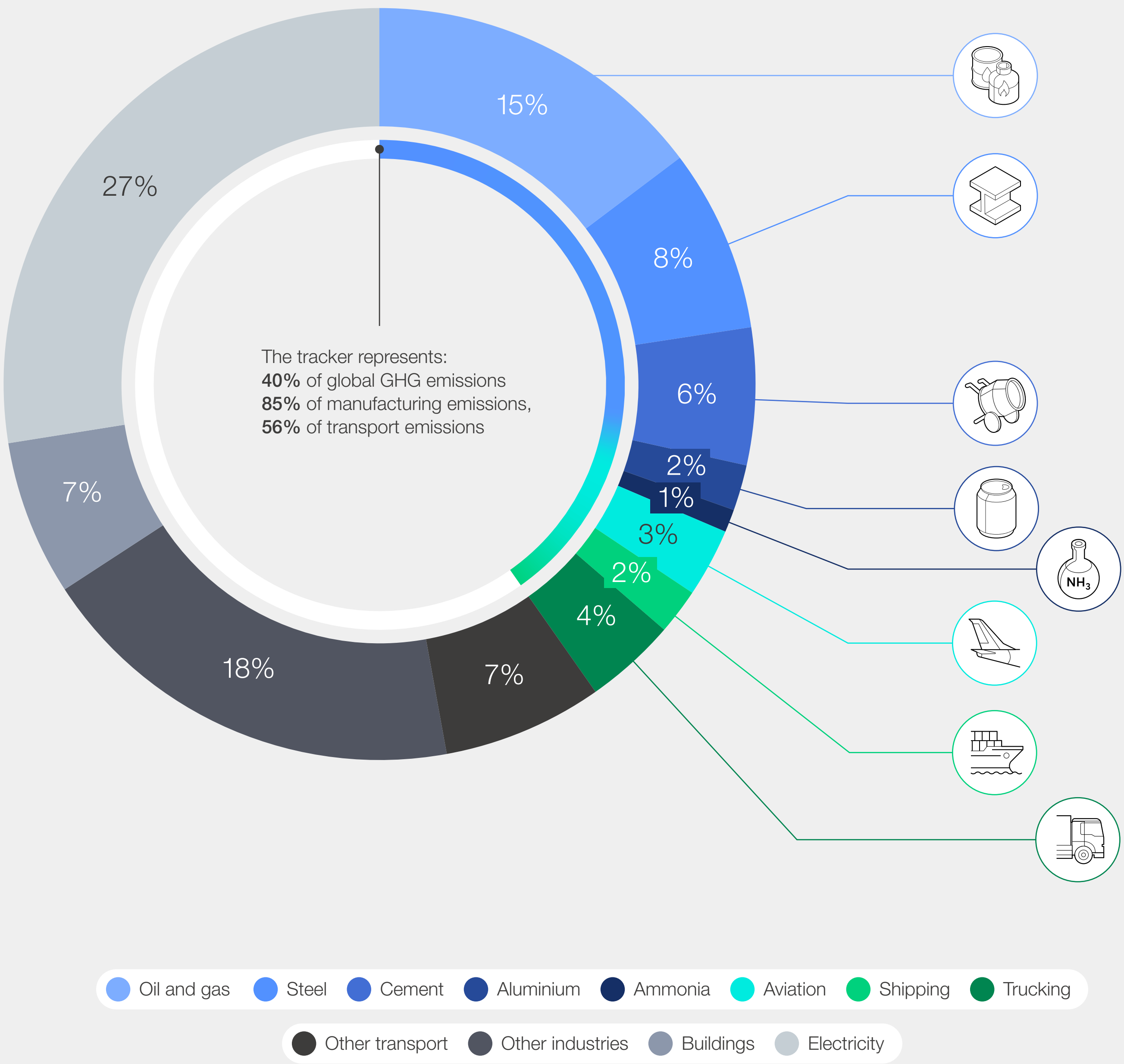
1

Cross industry findings

Industrial sectors, across production and energy, contribute over 30% of global GHG emissions, increasing to over 40% when combined with transport (see Figure 3). Currently, none of these sectors are on course to achieve net-zero emissions by 2050. Progress, in terms of emissions reduction and sector readiness has been limited in most regions over the past year.

Decarbonizing these emissions-intensive sectors is primarily dependent on removing the reliance on fossil fuels as the primary energy source and switching to renewable alternatives such as clean power and clean hydrogen, as well as efficiency improvements and abating emissions from any remaining fossil fuels.

FIGURE 3 **Global GHG emissions by sector**



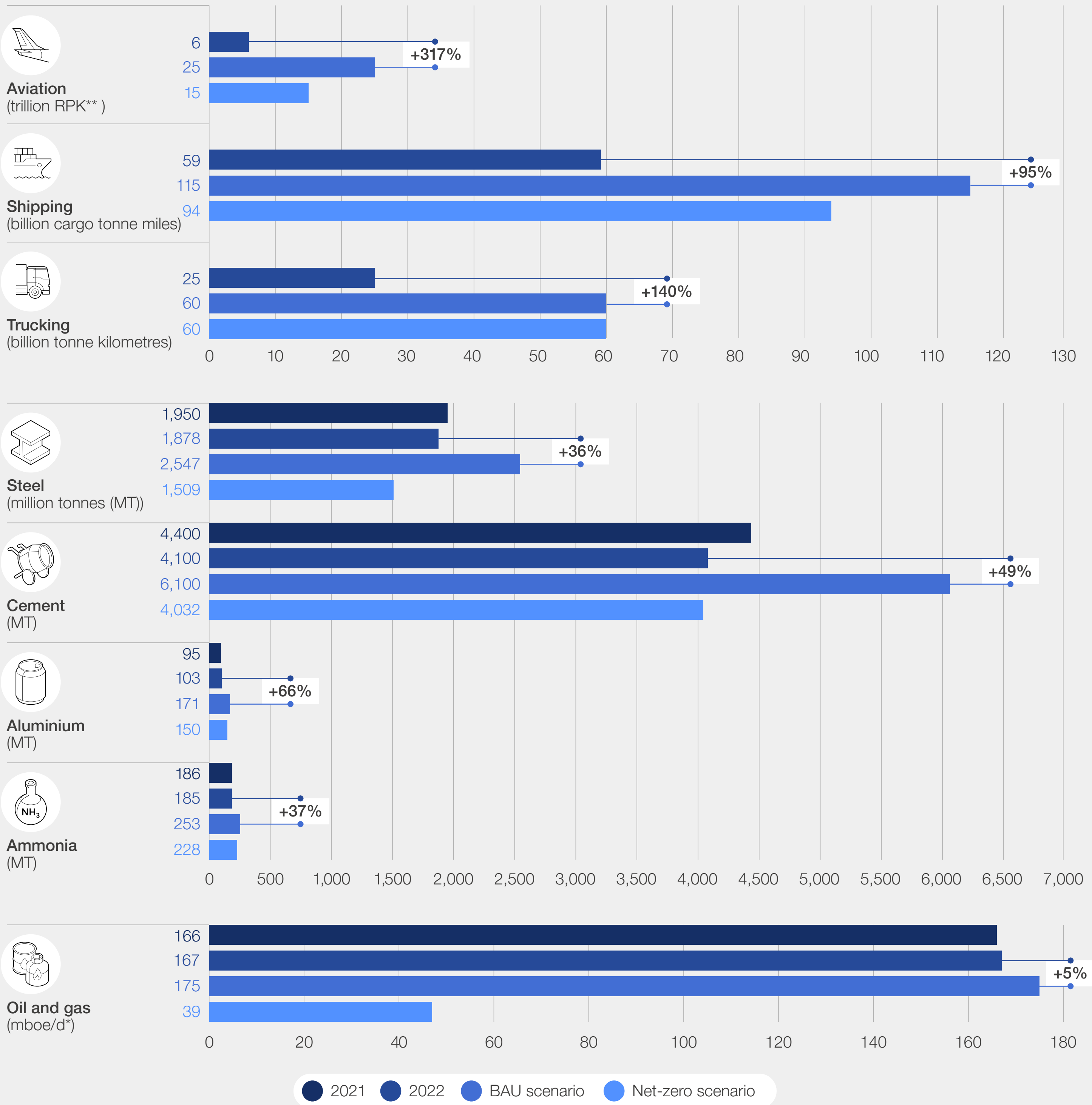
Source: Breakthrough Energy, *The Data, Sectoral Analysis*, n.d., https://breakthroughenergy.org/our-approach/the-data/sectoral-analysis/; IEA, *Net Zero by 2050*, 2021.

Low-emission products, fuels and technologies hold less than 1% market share in most sectors. This is because they are currently costly or hard to scale and many sectors prioritize near-term emission reduction solutions, while there's insufficient regulation, standards and consumer awareness about alternative products and their emission-cutting potential.

Positive advancements are underway in regions such as the US and the EU, where low-emission technologies are projected to gain traction by 2030. It is crucial to implement a customized blend of incentive-driven and mandate-based policies, considering the economic conditions of developing nations. Global companies need to take more substantial actions to expedite the transition.

As population growth, urbanization and economic expansion drive increased demand across all sectors, the carbon-intensive nature of these industries poses a formidable challenge to 1.5°C aligned climate goals. Prioritizing proactive decarbonization, coupled with the creation of employment and wealth, is imperative. However, adopting reactive measures risks higher costs, diminished competitiveness and a failure to meet emissions reduction targets. Industries need to de-couple emissions from demand by embracing innovative technologies, optimizing supply chains, transitioning to cleaner energy sources, encouraging policy collaboration and raising consumer awareness. Energy efficiency and energy savings can often be a quick way to achieve some reductions in emissions and energy consumption. However, there needs to be a complementary tool for developing and scaling technologies that can deliver deeper emissions cuts. Ultimately, in a 1.5°C aligned scenario, demand reduction through efficiency improvements, product diversification and substitution with low-emission alternatives will be needed.

FIGURE 4 **Demand increase from 2021 to 2050 under IEA stated policy and IEA net zero by 2050 scenarios**



*Thousand barrels of oil equivalent per day; **Revenue passenger kilometre

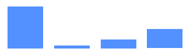
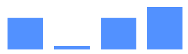
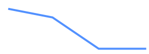
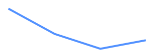
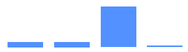
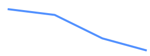
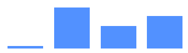
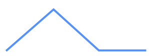
Source: IEA stated policy scenario and IEA net-zero scenario

Performance

Fossil fuels comprise more than 90% of the current energy mix, for sectors in scope. As such, the volume of absolute emissions increases alongside accelerating global demand. Absolute emissions increased by 8% between 2019 and 2022 across most sectors in scope. Though production and transport demand decreases are evident in the data through the course of the pandemic. Most sectors have recovered to or surpassed pre-pandemic demand levels, leading to a subsequent increase in emissions, emphasizing the need to dissociate emissions with demand growth and reduce energy intensity by substituting fossil fuels with renewables, new energy sources and increasing efficiency.

Emissions intensities have shown little reduction over the same time period, suggesting that all sectors require large-scale process and technology improvements. It is crucial to recognize that efficiency improvements that are important to reduce emissions may reach a plateau due to inherent process limitations. Therefore, fossil fuel substitution is equally key to reducing emissions intensities in line with 1.5°C scenarios.

TABLE 3 **Key performance metrics**

Sector	Absolute emissions growth* (2019-2022) (trend)	Absolute emissions growth (2019-2022) (%)	Emissions intensity growth (2019-2022) (trend)	Emissions intensity growth (2019-2022) (%)
Aviation**		-31		
Shipping***				
Trucking		2		-13.7
Steel****				-3.4
Cement		-0.3		0
Aluminium*****		4		-2.9
Ammonia		3		0
Oil and gas******		-4		

Source: IEA World Energy Outlook 2022

*Graph shows movement and trends across sectors, rather than direct unit by unit comparison; **Aviation emission intensity and emissions intensity growth excluded due to extreme outliers across COVID-19 pandemic period; ***Shipping figures from The Fourth IMO GHG study 2020, are based on 2018 data therefore excluded from this assessment; ****Historic absolute emissions data unavailable; *****Data available from 2019-2021; ******Emissions intensity trend not available.

The absence of precise sector-specific definitions for scientifically quantifying thresholds is a prevailing issue. Yet, the significance of establishing these benchmarks cannot be overstated, given that the predominant focus of current endeavours remains centred on high-emission trajectories. Currently, around 7% of production meets the existing thresholds of reduced emission production, defined as a percentage of production aligned with 2030 targets. Similarly, less than 1% meets low-emission thresholds, defined as the percentage of production aligned to 2050 thresholds. The trends over the last four years suggest that none of the sectors are on track to meet 2030 targets, and a significant acceleration of efficiency measures and low-emission technology adoption is needed.

BOX 3

Definitions

Absolute emissions are the total GHG emissions released from a specific source, measured in gigatonnes of CO_2 equivalent ($gtCO_2e$). Industrial production, oil and gas are assessed by scope 1 and 2 emissions. Transport sectors assessed by well to wake emissions.

Emissions intensity refers to the measure of greenhouse gas emissions per unit of activity or output measured in:

- Industrial production: Tonnes of CO_2 equivalent per tonne of output (tCO_2e/t)
- Oil and gas: Kilograms of CO_2 equivalent per barrel of oil equivalent ($kgCO_2e/boe$)
- Aviation: Grams of CO_2 equivalent per revenue passenger kilometre (gCO_2e/RPK)
- Shipping: Grams of CO_2 equivalent per tonne nautical mile ($gCO_2e/t\text{-}nm$)
- Trucking: Grams of CO_2 equivalent per tonne mile (gCO_2e/tnm)

Readiness

Reaching net zero by 2050 across industrial sectors is dependent on advancements in five key areas: technology, infrastructure, demand, policy and capital. This requires strategic actions to bolster technology, upgrade infrastructure, stimulate sustainable and low-intensity energy demand, develop effective policies, and secure the necessary capital investments. Achieving these objectives mandates a pragmatic and coordinated approach to promote sustainable growth and innovation.

TABLE 4

2023 industry enablers scores (arrows depict overall change across industries compared to 2022 scores)

Sector	Technology (—)	Infrastructure (—)	Demand (—)	Policy (↑)	Capital (↓)
Aviation	Stage 2	Stage 2	Stage 2	Stage 3	Stage 1
Shipping	Stage 3	Stage 2	Stage 2	Stage 2	Stage 1
Trucking	Stage 2	Stage 2	Stage 2	Stage 3	Stage 1
Steel	Stage 2	Stage 1	Stage 3	Stage 2	Stage 1
Cement	Stage 2	Stage 2	Stage 2	Stage 3	Stage 1
Aluminium	Stage 3	Stage 3	Stage 4	Stage 2	Stage 1
Ammonia	Stage 3	Stage 1	Stage 2	Stage 2	Stage 1
Oil and gas	Stage 4	Stage 2	Stage 3	Stage 3	Stage 3

Readiness stages: Stage 1 Stage 2 Stage 3 Stage 4 Stage 5

Technology

The technology landscape remains very similar to last year, with most technologies currently under development expected to reach commercial readiness by 2030. The transformation of emissions-intensive industrial and transport industries, where changes take a long time to incubate, heavily relies on technological innovation, active investments and industrial coordination and collaboration to share and replicate learnings. These sectors encounter distinct challenges, often centred around the imperative to reduce technology costs through strategies such as scaling up production, process optimization and deriving insights from initial deployments. In some instances, genuine technological revolutions are indispensable, as evidenced in sectors like aviation and cement production. As such, three net-zero technologies warrant prioritization for accelerated development:

1. **Increase clean power-based technology adoption across all sectors:** Clean power is expected to comprise up to 65% of the final energy mix by 2050 and is the least complex method of driving emissions reductions.

2. **Commercial scaling of carbon capture utilization and storage (CCUS) technology, particularly for cement:** With a lack of viable alternatives for net-zero cement, research and development (R&D), investment and additional projects are needed to improve applications for small and remote facilities and accelerate commercial scaling within this decade.

3. **Accelerated development of green hydrogen technology:** Access to green and blue hydrogen is an important decarbonization solution for several sectors. Despite positive developments in blue hydrogen, it is particularly important to significantly reduce costs and increase supply of green hydrogen to decarbonize and reduce fossil fuel dependence.

Furthermore, sector transition extends beyond the advancement of operational technologies; it equally emphasizes the critical necessity of integrating these innovations with established business systems. To expedite progress towards achieving net-zero emissions, it becomes imperative to prioritize the acceleration of technology readiness levels (TRLs). This goal can be realized through collaborative industry efforts and the development of new cross-industry partnerships.

65%
of the 2050 energy mix is expected to be clean power

FIGURE 5

Year by which industries could commercially deploy technologies enabling them to reach their 2050 low-emission intensity threshold

	Today	2025	2030
Aviation		Biobased SAF**	
Shipping	Methanol	Ammonia	
Trucking		Battery electric trucks (BETs)	
Steel		DRI-EAF* with carbon capture	
Cement			Carbon capture for cement kilns
Aluminium		Inert anodes	Hydrogen furnaces
Ammonia	Blue hydrogen		
Oil and gas	Combination of technologies required (see oil and gas technology page)		

Source: Accenture analysis based on multiple sources, including IEA and MPP

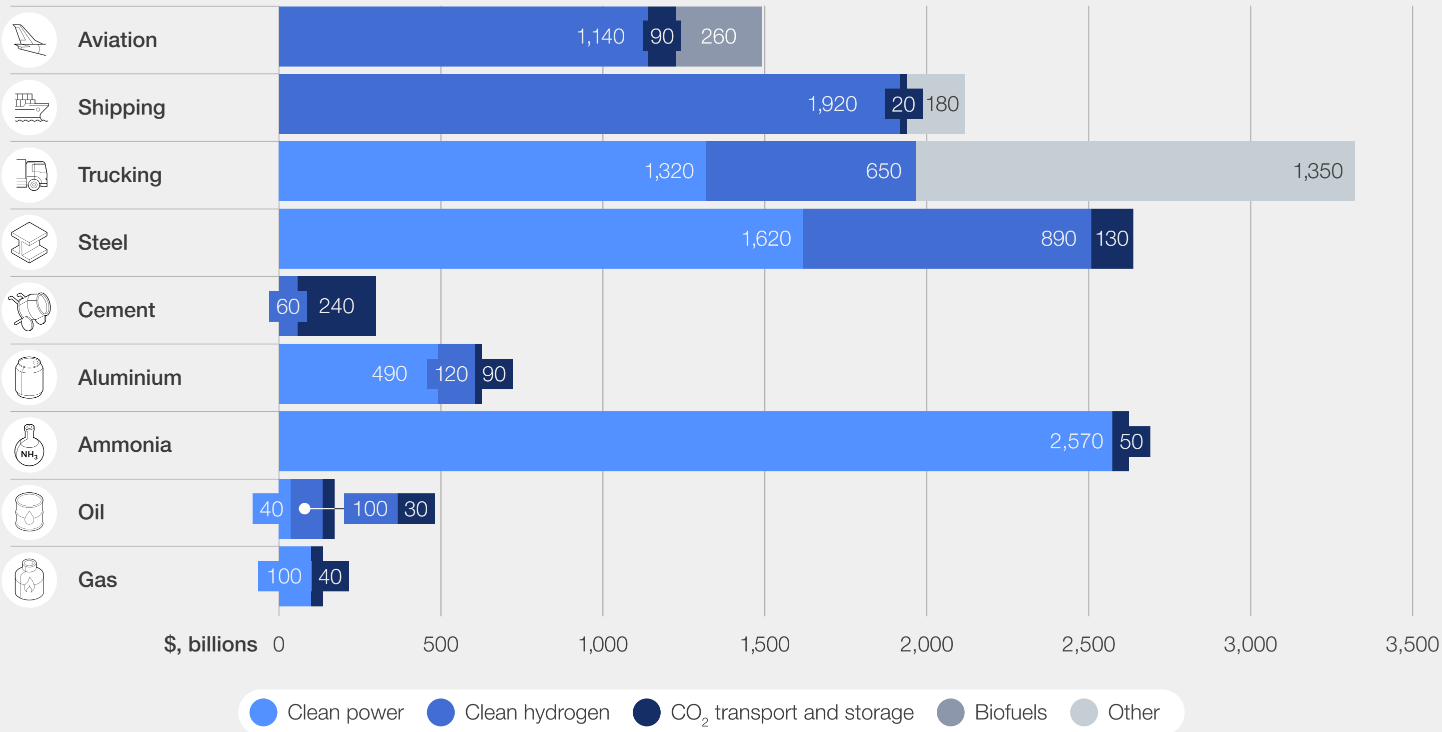
*Direct reduced iron-electric arc furnace **Sustainable aviation fuels

Infrastructure

Clean power, clean hydrogen and fossil fuels abated by CCUS will need to account for over 90% of the final energy mix for net zero by 2050 with applications across all sectors in scope, totalling around $13.5 trillion in investments (see Figure 7). Accelerating clean power generation and energy storage is crucial. The shift towards clean power sources requires significant changes in electricity procurement and markets, placing a growing emphasis on renewable energy procurement strategies, such as access to and coordination of a diverse set of industry players to include solar, nuclear and hydropower. A clean hydrogen economy is vital for industries like cement, steel and ammonia, while sectors like shipping and aviation are exploring hydrogen-derived fuels. Carbon capture capacity may need to increase by 120-125 times by 2050; however, inconsistent CCUS revenue models must be addressed.

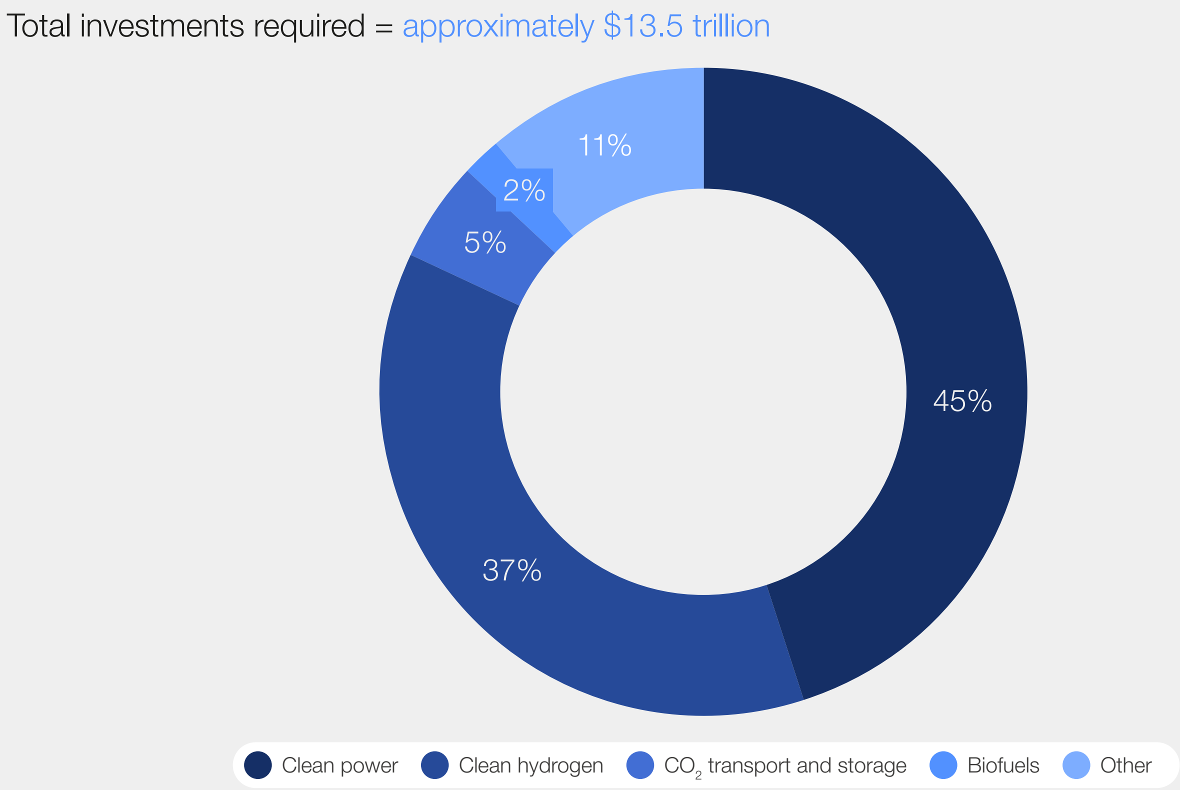
With less than 1% of the required infrastructure currently in place, the risk of cross-industry competition for limited resources grows as demand for low-emission products and transport rises towards 2050. **To tackle this, promoting shared infrastructure models like infrastructure hubs and industrial clusters can boost access to development, encouraging more equal sector growth and creating advantages of scale.** Industries should partner with infrastructure and energy providers to develop new contracts and complementary operational models. Bi-directional partnerships between two or more industries hold the potential to drive low-emission product demand through market opportunities and industrial applications.

FIGURE 6 **Total infrastructure investments by industry and by enabler by 2050**



Source: Accenture analysis based on multiple sources, including IEA, IRENA, Global CCS Institute and GMF

FIGURE 7 | **Total investments required by 2050 by enabler**



Source: Accenture analysis based on data from organizations including; Global Cement and Concrete Association, International Air Transport Association, International Energy Agency Net Zero by 2050 report and World Economic Outlook.

Demand

Early market demand signals are emerging in most sectors, supported by developing policies and an increase in offtake agreements and green subsidies. Initiatives such as the First Movers Coalition (FMC) have contributed to creating a stronger demand signal for innovative, clean technologies in industrial sectors. **Many production sectors have seen an increase in low-carbon alternatives over the last year. However, a lack of reporting standards, supply chain stability and transparency are consistent challenges across most sectors, with associated green premiums largely untested at the commercial scale.** The current industry dilemma regarding whether to stimulate demand or supply requires immediate attention and resolution. Industry leaders and consortia share a unanimous commitment to developing net-zero pathways, though the absence of reliable customer revenue signals both in terms of price and volume limit execution. This uncertainty poses challenges for businesses looking to invest in and pursue potentially transformative but uncertain opportunities. Industries need to collaborate across the value chain to create transparency around applications of clean technologies, clarify infrastructure demand requirements and prioritize accordingly, reducing the energy intensity of process activities.

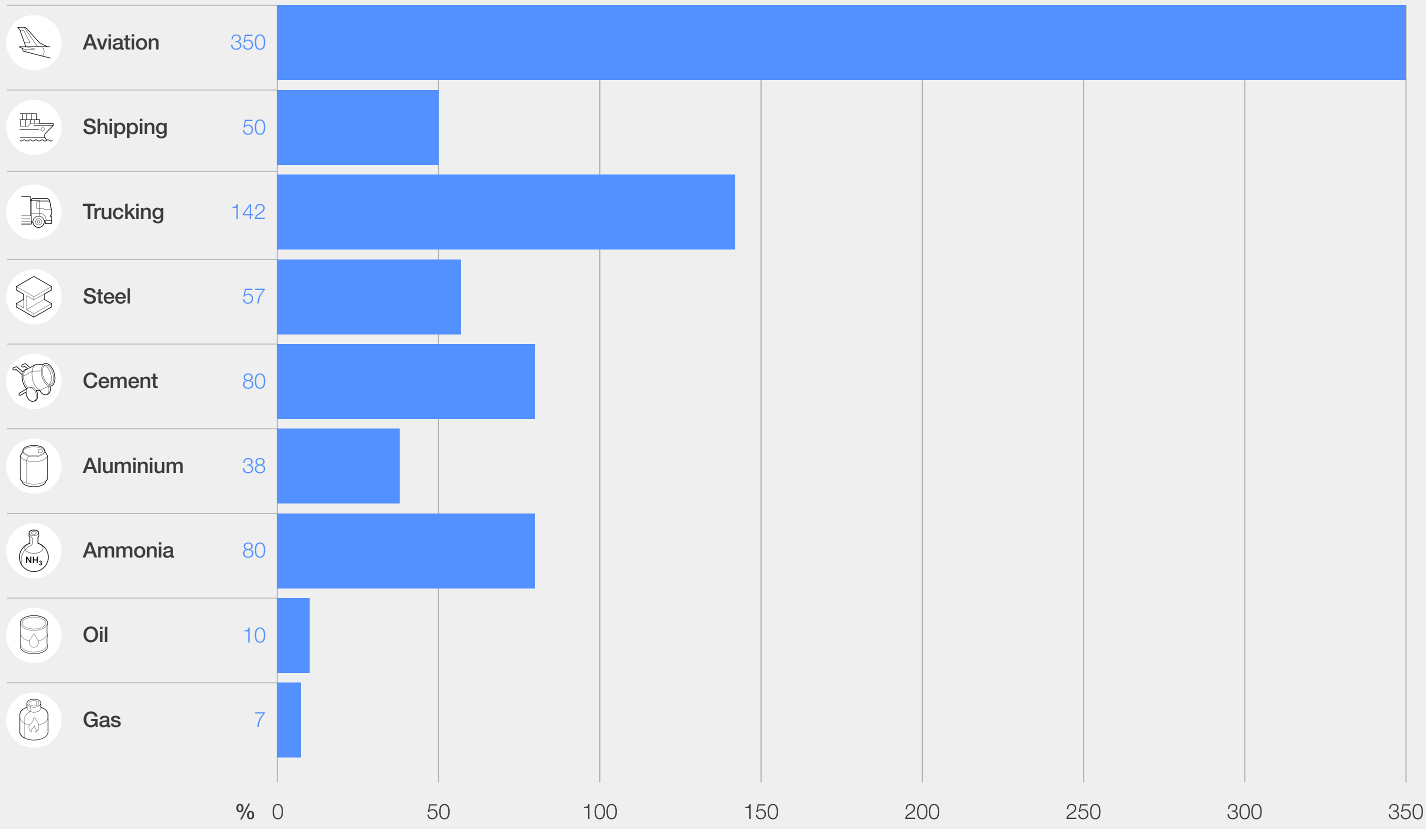
The industry dilemma regarding whether to stimulate demand or supply requires immediate attention and resolution.

Across various sectors, several key prerequisites have emerged as essential for creating demand for low-emission products and raising consumer awareness of product and service carbon attributes. These prerequisites include:

1. A standardized framework for low-emission products
2. A simple-to-deploy emissions intensity calculator
3. An auditable carbon footprint assessment process.

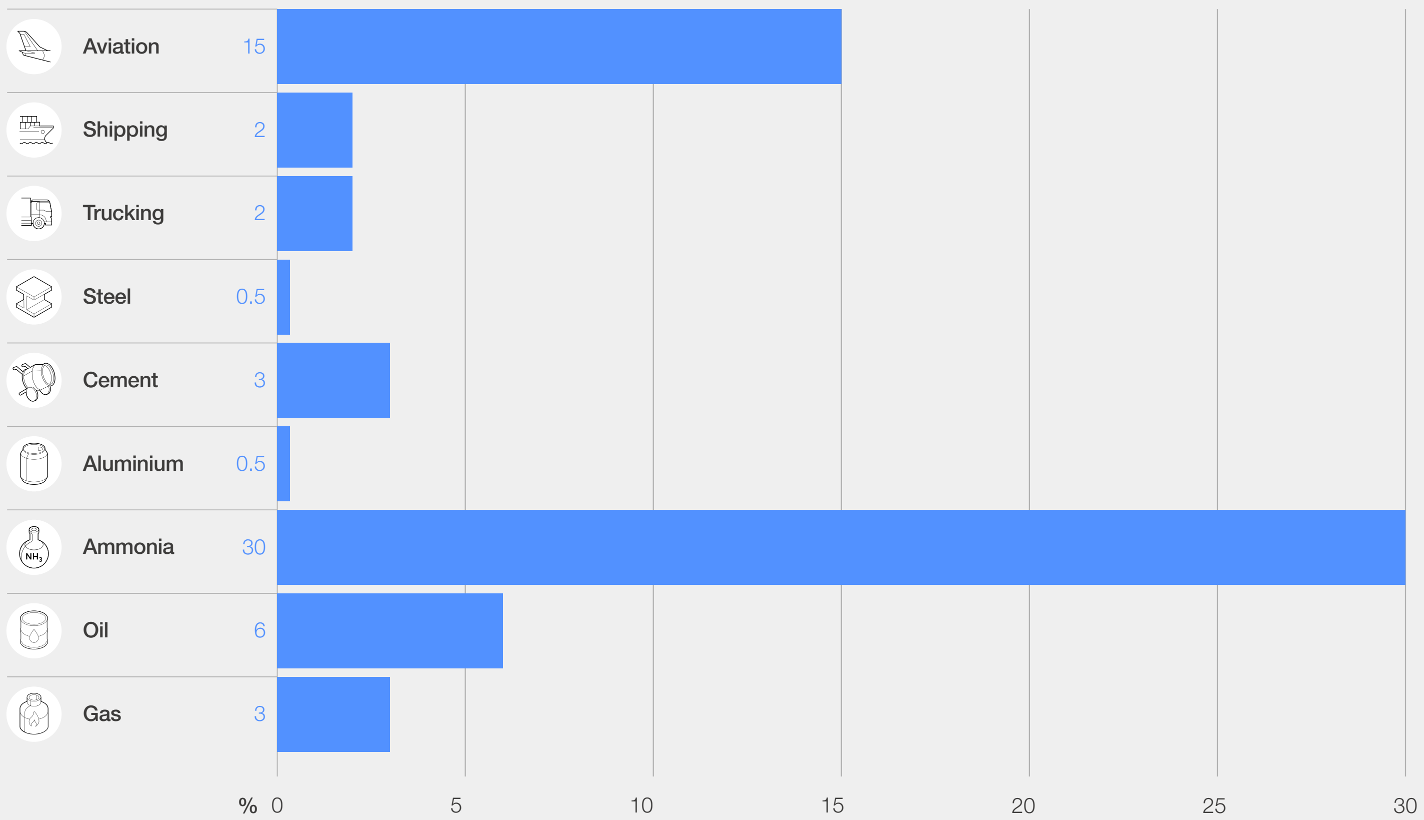
Notably, the aviation sector has made progress in promoting transparency through the use of carbon footprint calculators. Similarly, the construction sector has taken steps to certify green products, especially in the context of low-emission buildings, although it has historically excluded primary materials from these certifications. While these sectors serve as commendable examples, it is imperative for other industries to follow suit and adopt similar measures.

FIGURE 8 | Average business to business (B2B) green premium by current estimates



Source: Accenture analysis based on multiple sources, including MPP, ETC, Bloomberg and IEA

FIGURE 9 | Average business to consumer (B2C) green premium by current estimates



Source: Accenture analysis based on multiple sources, including MPP, ETC, Bloomberg and IEA

Policy

Policy plays a pivotal role in sectoral decarbonization, serving dual objectives: advancing climate goals and bolstering demand and economic resilience. It must also navigate the delicate equilibrium between domestic economic growth and the expenses tied to supply chain onshoring. Major producing countries/regions such as China, India, the US and the EU have now committed to net-zero targets, making it imperative for businesses within their jurisdictions to align their operations and strategies with the evolving regulatory landscape. However, complex and ever-changing policy regimes result in businesses allocating substantial resources towards compliance, impeding progress. Establishing more consistent and stable regulatory frameworks with well-defined timelines is imperative for mitigating these risks.

Emerging signals indicate a range of cross-sectoral policy systems being tested worldwide:

- Currently, 20% of countries have implemented various forms of carbon pricing to incentivize a shift away from emission-intensive production routes. Additionally, import control programmes, like the EU's Carbon Border Adjustment Mechanism (CBAM), complement these measures.

- In countries like China and India, national-level action plans and roadmaps for clean hydrogen have been adopted to encourage investments across the hydrogen value chain that aid large-scale industrial transformation. Also, the G20 member countries have agreed to guiding principles that enable the production, consumption and global trade of clean hydrogen.

- Several countries have introduced policies to enable CCUS technology and infrastructure developments. These include carbon capture and storage (CCS) investment tax credits in Canada, the EU's Innovation Fund for CCS projects, and Japan's commitment to develop a CCS-specific regulatory framework.

- Comprehensive policy packages like US' Infrastructure Investment and Jobs Act (IIJA) and Infrastructure Investment and Jobs Act (IRA) that provide fiscal stimulus to multiple areas of industrial decarbonization have also been deployed.

- While the above policies address the supply side, demand side measures such as green public procurement (GPP) are advancing, with Clean Energy Ministerial's Industrial Deep Decarbonisation Initiative (IDDI) driving global GPP commitments in heavy industries.

While these policy systems show promise, it's important to note that their applicability varies across different sectors, particularly in addressing emissions-intensive sectors across industry, energy and transport. Each sector demands specific, well-defined policies and regulations that align with evolving consumer revenue models. Furthermore, there is an urgent need for effective cross-regional policies that bridge the current disparities among regions, which are impeding global CO_2 emissions reduction efforts.

20%
of countries have carbon pricing mechanisms

Capital

An additional $11 trillion is required by industries to retrofit existing assets with clean technologies and order a new zero-emission fleet outside the BAU asset renewal cycle. For some industries, like cement, this means attracting almost double their annual CapEx to invest in clean technologies. However, the current market landscape lacks sufficient incentives to invest in low-emission technologies and poses a risk to early investors across most sectors.

Industry collaboration is imperative to reduce costs, accelerate learning curves and establish market stability to incentivize greater investment in decarbonization efforts. Industrial decarbonization requires the pooling of collective knowledge and resources across sectors; both start-ups and incumbents have a role to play. Collaboration allows for the efficient exchange of expertise and assets, leading to the development of more economically viable decarbonization technologies. This cooperative approach not only alleviates the financial burden on individual sectors but also creates market predictability. A stable and predictable market environment is paramount in attracting increased investments in decarbonization initiatives and cultivating stakeholder confidence.

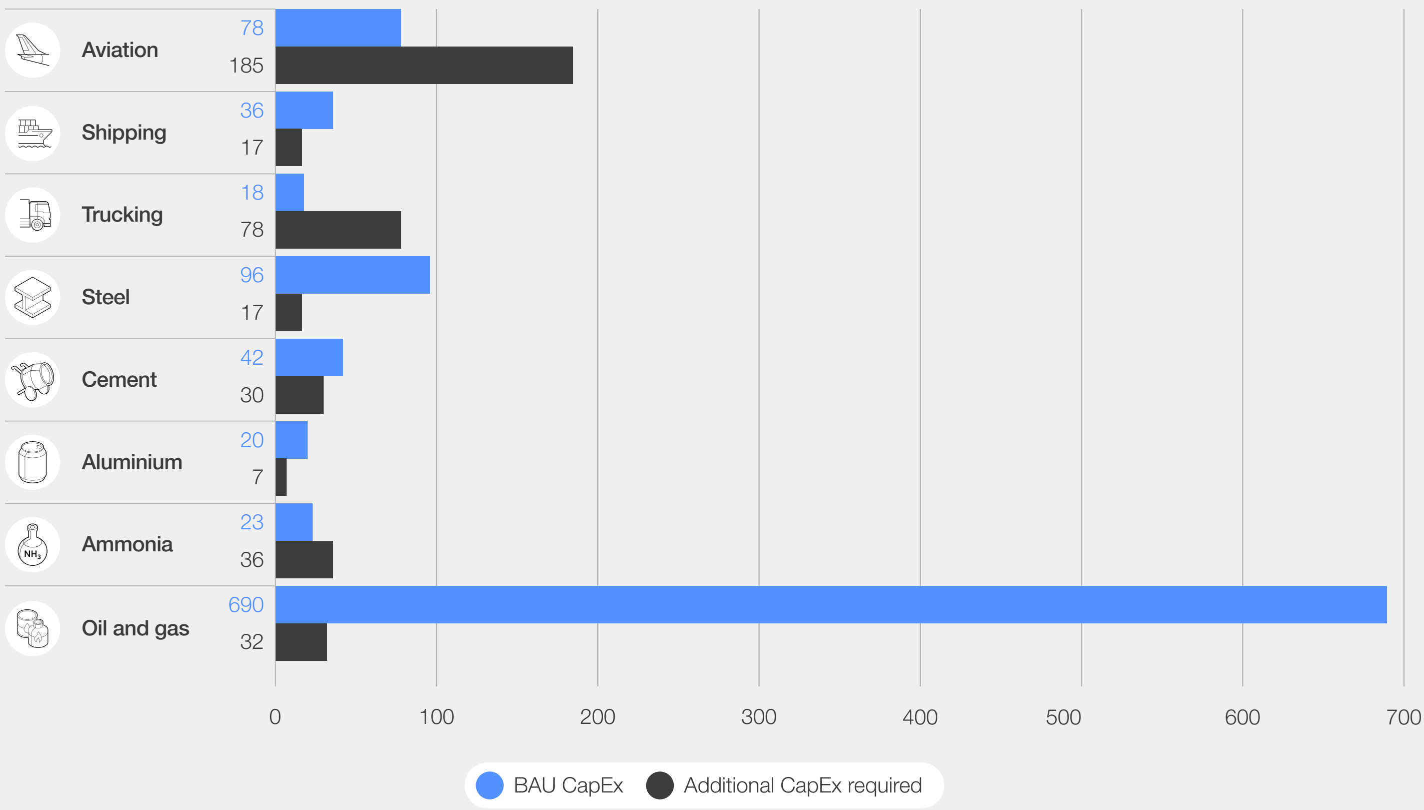
Redirecting capital for industry transformation requires strategic policy interventions, including carbon pricing, technology subsidies, public procurement and a strong business case. Institutional investors and multilateral banks can play a crucial role by providing access to low-cost capital linked to emissions targets. However, adapting financial models to align with the specific needs of various industries and regions is equally vital to mobilizing the necessary capital.

Many companies have demonstrated their commitment to reducing emissions by integrating emission considerations into their decision-making processes. Some companies exhibit a more comprehensive approach, providing detailed emissions reporting and clear emission reduction targets. However, a significant portion of companies lag behind, limited to basic emission reporting and reduction targets, particularly in developing countries.

Current industry profit margins indicate that many industries are ill-prepared to absorb additional costs while generating sufficient returns. To improve access to capital and generate sustainable returns, improved transparency surrounding low-emission and low-carbon alternatives is needed. Strengthening demand signals, particularly for new technology applications, is key. Collaborative infrastructure development across regions can play a pivotal role in mitigating early investor risk, reducing CapEx requirements for individual sectors, and ultimately leading to more substantial and sustainable returns on investment.

To improve access to capital and generate sustainable returns, improved transparency surrounding low-emission and low-carbon alternatives is needed.

FIGURE 10 **Estimated annual CapEx vs BAU annual CapEx ($, billion)**



Source: Accenture analysis based on multiple sources to include IEA, EMSA, MPP and IATA

FIGURE 11 | Actions to support net zero industrial transformation

For policy-makers:

1. Implement nationally tailored incentive and mandate-based policies, such as tax subsidies and emissions caps to stimulate demand for low-emission technologies, especially in developing regions. Policy measures need to be tailored to national circumstances and fiscal capabilities.
2. Implement carbon pricing in all major production regions and main transport hubs.
3. Increase green public procurement and public/private partnerships to provide early demand signals for low-carbon products and mitigate early investor risks.

For industry:

1. Support regulations and standards and clarifying net zero and transition technologies to improve transparency for producers, investors and end-consumers
2. Collaborate across sectors for improved infrastructure access and faster development.
3. Increase the number of offtake agreements by 2030 to stimulate early low-emission technology demand.

For companies:

1. Embed measurable net zero targets and pathways into their long-term strategies.
2. Invest in R&D and deployment to accelerate the learning curve for lagging low-emission technologies.
3. Enhance access to infrastructure and implement decarbonisation solutions within this decade.

Decarbonizing industrial sectors requires collective collaboration among policy-makers, industry consortia and companies.

Conclusion

In this decade characterized by economic expansion and soaring demand for goods and transport, the paradoxical challenge of simultaneously addressing climate change and creating economic growth and resilience remains ever-present. While there is a notable increase in awareness and action within industries striving for net-zero emissions, it is apparent that none of the emissions intensive industry sectors, across production, energy and transport, is currently on course for achieving net-zero emissions by 2050, signifying that substantial challenges lie ahead.

To steer towards the path of progress, individual companies and industries must forge ahead on multiple fronts. However, it is crucial to recognize that they cannot embark on this journey in isolation. An entire ecosystem of stakeholders and factors must contribute and unite towards the common goal of making new technologies commercially viable and rapidly scaling existing ones. This requires active participation from companies throughout the value chains of supply and demand, as well as policy-makers. Aligning the essential components of demand for sustainable products, policy incentives, capital for technology investments and infrastructure expansion is the key to accelerating progress in these industries.

Industrial decarbonization stands as one of the most daunting challenges in the ongoing energy transition. Every country and industry faces the intricate task of striking a delicate balance, one that involves the need to promote domestic benefits and create quality jobs while upholding the principles of free trade and open markets.
In this multifaceted endeavour, cooperation and coordinated efforts among all stakeholders, both domestic and international, will be critical to surmount the challenges and realize a sustainable, resilient and decarbonized future. While challenging, the time for action is now.

2

Aviation industry net-zero tracker

SAF are considered key to decarbonizing aviation, but current commercial limitations mean that SAF only provides around 40% emissions reduction.

Key emissions data[2,3,4,5]

2%
Contribution to global GHG emissions

0.98 $gtCO_2e$
Operational and fuel supply chain emissions

-25%
Emissions growth (2019-2022)

>99%
Fossil fuels in the fuel mix (2022)

83 gCO_2e
Emissions intensity emitted per passenger km (2020)

2-5 times
Expected demand increase by 2050

Readiness key takeaways

Technology
Two leading decarbonization pathways have emerged: mature SAF and less mature novel propulsion technologies. However, the most advanced pathway is 2-5 times higher cost than traditional jet fuel.[6]

Infrastructure
$2.4 trillion[7] in infrastructure investment is required to support the development and scaling of aviation technology by 2050.

Demand
Although SAF adoption was less than 1%[8] of flights in 2022, there is a growing shift towards sustainable business models and agreements supporting its use.

Policy
Current policies primarily target developed countries, but further policy advancements are needed, like tax subsidies, direct funding and additional fuel standards, to incentivize biofuels infrastructure.

Capital
The industry needs approximately $5 trillion by 2050[11], far exceeding current airline investments. Low-profit margins and a 7% weighted average cost of capital (WACC) make it hard to attract private capital for low-emission assets.[12]

Stated energy transition goals

- Net-zero emissions by 2050.[9]
- 73%[10] of large publicly traded aviation companies consider climate change in their decision-making processes.

Emission focus areas for tracker

Aviation emissions can be divided into two main categories:

1. **Well-to-tank** mainly upstream emissions from production and distribution of fossil fuels
2. **Tank-to-wake** primarily due to combustion of fossil fuels, predominantly jet fuel, used during flight operations.

Sector priorities

Exisiting transport
Reduce near-term emissions intensity by:
- Increasing the number of operational synthetic fuel projects
- Increasing biofuels refining capacity to support additional commercial scale hydroprocessed esters and fatty acids (HEFA) projects
- Using efficiency and design improvement opportunities at an accelerated pace.

Next generation transport
Accelerate battery electric and hydrogen technology development, to reduce absolute emissions by:
- Investing in next generation transport R&D and accelerating the learning curve
- Developing hydrogen storage capacity and refuelling capabilities
- Investing in clean power infrastructure.

Ecosystem
De-risk capital investment to scale infrastructure capacity by:
- Increasing the number of offtake agreements, strengthening market demand signals
- Accelerating power to liquids (PtL) development, mitigating biofuels supply chain limitations
- Implementing a blend of policies, primarily, tax subsidies, direct funding and additional fuel standards, incentivizing biofuels production.

3 Shipping industry net-zero tracker

Despite the rise in emissions, a more ambitious IMO strategy and industry actions towards technology adoption positions shipping on a positive track for a net-zero pathway.

Key emissions data[68, 69, 70, 71]

2%

Contribution to global GHG emissions

0.76 gtCO_2e

International shipping GHG emissions (2018)

11.7 gtCO_2e

Emissions intensity (emitted per tonne nautical miles, 2018)

99%

Fossil fuels in the fuel mix (2021)

2 times

Expected demand increase by 2050

Readiness key takeaways

Technology

Transitioning to clean, hydrogen-based, zero-emission fuels (ZEF) like methanol and ammonia, could nearly eliminate shipping emissions. However, uptake faces costs and infrastructure challenges.

Infrastructure

Currently less than 1% of the necessary infrastructure exists, requiring about $0.4-0.6 trillion investment to support the development and scaling of shipping technology by 2050.[72]

Demand

Growing demand for low-carbon shipping faces uncertainty as B2B green premium of 30-80% remains mostly untested at scale.[73]

Policy

To meet IMO targets, policies should encourage low-emission fuels and operational efficiency through measures like carbon pricing, fuel standards and incentives for infrastructure.

Capital

Adopting ZEF propulsion for ships by 2050 requires up to $450 billion investment,[76] adding 47% to annual fleet owner costs, which are currently around $36 billion.[77]

Stated energy transition goals

- United Nations (UN) specialized agency IMO aims for at least 20%, striving for a 30% reduction in absolute emissions by 2030 (vs 2008) and net-zero emissions by or around 2050.[74]
- 51% of large publicly traded shipping companies consider climate change in their decision-making processes.[75]

Emission focus areas for tracker

Shipping emissions can be divided into two main categories considering well-to-wake:

1. **Operational emissions are** primarily due to the combustion of fossil fuels during maritime operations.
2. **Fuel value chain emissions** are mainly upstream emissions from the production and distribution of fossil fuels.

Sector priorities

Existing transport

Reduce near-term emissions intensity by:

- Accelerating design and efficiency improvements aligned with IMO guidelines
- Increasing share of fleet capable of running on alternate fuels supported by technology standards
- Explore feasibility of complementary solutions in the interim (e.g. wind-assisted propulsion).

Next generation transport

Accelerate clean hydrogen-based fuels development, to reduce absolute emissions by:

- Investing in next generation fuels and propulsion technology R&D
- Ramping up the required clean hydrogen-based fuels production capacity
- Developing the required bunkering capacity, with storage and refuelling infrastructure.

Ecosystem

De-risk capital investment to scale infrastructure capacity by:

- Implementing green corridors in major routes supported by clean hydrogen hubs
- Bridging the cost gap between ZEFs and conventional fuels through increased number of projects
- Implementing a blend of policies, primarily carbon pricing and fuel standards.

4 Trucking industry net-zero tracker[137]

Battery and hydrogen-powered electric trucks are considered vital for net-zero trucking, but adoption depends on region, duty cycle and supporting policies.[138]

Key emissions data[139, 140, 141]

5%
Contribution to global energy related GHG emissions

1.6 gtCO_2e
Operational and fuel supply chain emissions

2%
Emissions growth (2019-2022)

108 gCO_2
Emissions intensity (emitted per tonne miles, 2020)

96%
Fossil fuels in the fuel mix (2021)

2-2.5 times
Expected demand increase by 2050

Readiness key takeaways

Technology

Two key zero-emission pathways are emerging, battery electric trucks (BETs) and hydrogen-electric trucks (HETs), which can nearly eliminate tailpipe emissions. Adoption is limited to around 1% partly due to increased ownership costs (33-133%[142]).

Infrastructure

Insufficient infrastructure, less than 1% of the needed amount, hinders technology scaling. Meeting 2050 goals requires a $2-$3.2 trillion[143] in investment, primarily into clean power infrastructure.

Demand

Zero-emission vehicles (ZEVs) held 1% of the market in 2022. A B2B green premium of 10-15% may be necessary, with about 1-3% affecting consumers.[144] However, this remains untested at scale.

Policy

Public policy encourages ZEV adoption, with the EU taking the lead, but the industry is diverse and regulated at various levels. More policies are needed to support infrastructure development.

Capital

Additional capital requirements, including retrofitting the existing fleet requires a $2.1 trillion[146] in investment. However, the business case remains weak due to high costs and uncertain returns, given 6% industry profit margins and a 10% WACC.[147]

Stated energy transition goals

– Industry bodies propose an emissions reduction of 14% by 2030 and 92% by 2050.[145]

Emission focus areas for tracker

Trucking emissions can be divided into two main categories:

1. **Well-to-tank** mainly upstream emissions from production and distribution of fossil fuels.
2. **Tank-to-wake** primarily due to combustion of fossil fuels, predominantly diesel, used during trucking operations.

Sector priorities

Exisiting transport

Reduce near-term emissions intensity by:

- Accelerating the adoption of drop-in biofuels and synfuels in the interim
- Introducing standards and regulations around legacy vehicle decommissioning cycles
- Making use of efficiency and design improvement opportunities at an accelerated pace.

Next generation transport

Accelerate clean power infrastructure development, to reduce absolute emissions by:

- Investing in R&D to accelerate ultra-fast charging infrastructure deployment
- Investing in clean power infrastructure to increase access to renewable energy sources
- Accelerating development of hydrogen-electric technologies for long-haul applications.

Ecosystem

De-risk capital investment to accelerate technology adoption by:

- Increasing incentive-based policies such as tax subsidies to drive charging infrastructure deployment
- Implementing a blend of policies to incentivize accelerated fleet renewal outside BAU cycles.

Notes: 1 The scope of analysis covers the hard-to abate aspect of the Trucking industry, primarily heavy-duty trucking **2** Regions in scope for trucking analysis, based on MPP framework; US, China, India, EU

5 Steel industry net-zero tracker

For primary steelmaking clean hydrogen-based DRI-EAF has emerged as the main decarbonization pathway, whereas secondary steel needs to switch to clean power sources.

Key emissions data[202, 203, 204, 205]

8%
Contribution to global energy related GHG emissions

3.7 $gtCO_2e$
Scope 1 and 2 emissions

1.41 tCO_2
Emissions intensity (per tonne of steel, 2022)

22%
Reduced emission production

>85%
Fossil fuels in the fuel mix (2022)

1.4 times
Expected demand increase by 2050

<1%
Current low-emission production

Readiness key takeaways

Technology

Primary steel[206] can use both clean hydrogen and CCUS for decarbonization. Secondary steel[207] can use EAF with renewable electricity. However, costs are 40-70%[208] higher than traditional methods.

Infrastructure

Inadequate infrastructure requires $1.8-2.4 trillion[209] for clean hydrogen and clean power development. Regions with steel capacity and access to affordable renewables and CO_2 storage should be prioritized.

Demand

Near-zero-emission steel held less than 1% of the market in 2022. A B2B green premium of 40-70% may be necessary, with about 1-2% affecting consumers.[210] However, this remains untested at scale.

Policy

Early-stage steel decarbonization policies are needed especially in Asia-Pacific (with 70% global steel production). Policies should focus on clean power, hydrogen, R&D and green procurement for low-emission steel.

Capital

$372 billion[213] is required by 2050, with 60% directed towards retrofitting existing assets. However, the business case remains weak, given 8.5% industry profit margin and 10.1% WACC.[214]

Stated energy transition goals

– The industry targets a 45% reduction in intensity for primary steel and a 65% reduction for secondary steel by 2030, and net-zero emissions by 2050.[211]
– 70%[212] of large publicly traded steel companies consider climate change in their decision-making processes.

Emission focus areas for tracker

Steel emissions can be divided into two main categories:

1. **Energy-related emissions** are primarily due to coal use in the blast furnace-basic oxygen furnace (BF-BOF) and EAF processes to produce molten steel for primary steel production.
2. **Process-related emissions** emanate from the use of coke or natural gas as a reducing agent to convert iron ore into iron for primary steel production.

Sector priorities

Existing assets

Reduce near-term emissions intensity by:

– Deploying energy efficiency improvement techniques
– Shifting to transitional technologies such as DRI-EAF in regions where natural gas is affordable and available
– Switching to clean power sources for secondary steel production, where cost competitive renewables are feasible.

Next generation assets

Accelerate infrastructure development to drive absolute emissions reduction by:

– Investing in clean hydrogen generation capacity to support transition for primary steelmaking
– Retrofitting assets with CCUS where access to CO_2 transport and storage is economical
– Enabling access to grid-based clean power for secondary steel.

Ecosystem

Enabling access to grid-based clean power for secondary steel by:

– Implementing a blend of policies, principally product standards and incentivizing low-emission production
– Reducing near-zero-emission production costs through an increased number of clean hydrogen projects
– Enabling shared infrastructure and supply chain stability through strategic partnerships.

6

Cement industry net-zero tracker

While increased use of alternative fuels is a positive signal, CCUS adoption remains critical for net zero and needs to scale from less than 1% to 90% by 2050.

Key emissions data[263, 264, 265, 266, 267]

- **6%** — Contribution to global GHG emissions
- **2.6 $gtCO_2e$** — Scope 1 and 2 emissions
- **-0.3%** — Emissions growth (2019-2022)
- **0.58 tCO_2** — Emissions intensity (per tonne of cement, 2022)
- **92%** — Fossil fuels in the fuel mix (2020)
- **1.5 times** — Expected demand increase by 2050
- **<1%** — Current low-emission production
- **<1%** — Reduced emission production

Readiness key takeaways

Technology

Cement can use CCUS (TRL 6-9), clean hydrogen and clean power (TRL 5-6) for decarbonization – however, production costs are nearly double that of Portland cement.

Infrastructure

Less than 1% of infrastructure is installed today, requiring investments of up to $300 billion by 2050.[268] Rich CO_2 streams from clinker position cement as a primary candidate for CCUS.

Demand

Near-zero-emission cement held less than 1% of the market in 2022. A B2B green premium of 60-100% may be necessary, with about 1-3% affecting consumers.[269] However, this remains untested.

Policy

Early-stage cement decarbonization policies needed especially in Asia-Pacific (with 70% global cement production[270]). Policies should focus on technology incentives, carbon pricing, near-zero-emission cement standards and updated building codes.

Capital

$750-900 billion CapEx required by 2050.[272] The business case remains weak, given 11% industry profit margin and 10% WACC.[273]

Stated energy transition goals

– Industry aims for a 25% emissions intensity reduction by 2030 and net-zero emissions by 2050.[271]

– 61% of large publicly traded cement companies consider climate change in their decision-making processes.

Emission focus areas for tracker

Cement emissions can be divided into two main categories:

1. **Energy-related emissions** arise from fossil fuel used in kiln heating, material grinding and machinery operations. High temperatures transform raw materials into clinker, releasing CO_2 and other GHGs.
2. **Process emissions** stem mainly from chemical reactions during raw material conversion to clinker, emitting CO_2 through limestone calcination.

Sector priorities

Existing assets

Reduce emissions intensity of clinker production by:

– Increasing fuel substitution with biomass and renewable waste[274]

– Reducing thermal energy consumption through efficiency improvements

– Substituting clinker with supplementary cementitious materials (SCMs) and reducing the clinker-cement ratio.[275]

Next generation assets

Accelerate infrastructure development to drive absolute emissions reduction by:

– Investing in CO_2 storage and transport infrastructure

– Retrofitting cement kilns with clean hydrogen capability

– Enabling access to grid-based clean power and deploying electrified kilns.

Ecosystem

De-risk capital investment to scale technology by:

– Implementing a blend of policies, principally carbon pricing

– Incentivizing near-zero-emission production, reducing low-emission production costs through an increased shared CCUS projects at industrial hubs

– Enabling shared infrastructure and supply chain stability through strategic partnerships.

7 Aluminium industry net-zero tracker

To reach net zero, the industry will need to increase use of clean power, improve the share of recycled aluminium and progress low-emission smelting and refining technologies.

Key emissions data[325, 326, 327, 328, 329, 330]

3%
Contribution to global GHG emissions

1.2 gtCO_2e
Scope 1 and 2 emissions

4%
Emissions growth (2019-2021)

11.2 tCO_2
Emissions intensity (per tonne of aluminium, 2021)

67%
Fossil fuels in the smelting power mix (2021)

1.7 times
Expected demand increase by 2050

<1%
Current low-emission primary production

47%
Reduced emission primary production

Readiness key takeaways

Technology

Aluminium should use clean power and scrap to reduce its emissions. Low-emission refining and smelting methods are proposed to be accessible by 2030. Production costs for low-emission aluminium can be up to 40% higher than traditional methods.[331]

Infrastructure

30% of clean power infrastructure exists while current hydrogen and CO_2 transport infrastructure is below 1% of what is required by 2050.[332] Investments of up to $560 billion[333] are needed to accelerate infrastructure development.

Demand

Low-emission aluminium held less than 1% of the market in 2022. A B2B green premium of around 40%[334] may be necessary, with about 1-2% affecting consumers.[335] However, this remains untested.

Policy

Global aluminium trade requires both domestic and international regulations for decarbonization. Key producing countries, such as China, require more tangible policies especially focused on improving access to clean power infrastructure.

Capital

Over $200 billion in CapEx[338] is required by 2050 to retrofit existing assets with inert anode technology and low-emission smelting technology. However, the business case remains weak, given 8% industry profit margin and 9% WACC.[339]

Stated energy transition goals

- Current industry net-zero scenarios propose a 30% reduction in emissions intensity by 2030 and 97% emissions by 2050.[336]
- 71%[337] of large publicly-traded aluminium companies consider climate change in their decision-making processes.

Emission focus areas for tracker

Aluminium emissions can be divided into two main categories:

1. **Energy-related emissions** primarily due to fossil-based electricity consumption during smelting and thermal energy consumption during refining.
2. **Process emissions** from smelting requiring the presence of carbon-based anodes.

Sector priorities

Exisiting assets

Reduce near-term emissions intensity by:

- Switching to clean power sources for smelting operations where feasible
- Retrofitting existing fossil-fuel-based captive power assets with CCUS, where access to clean power grids is not economical
- Improving end-user scrap collection rate from 70% currently to maximize secondary production.[340]

Next generation assets

Accelerate technology and infrastructure development to drive absolute emissions reduction by:

- Investing in clean power grid capacity supported by energy storage systems to support transition
- Accelerating market readiness for low-emission smelting technologies like inert anodes
- Develop and deploy low-emission refining technologies like electric boilers, mechanical vapour recompression, etc.

Ecosystem

De-risk capital investment to scale infrastructure capacity by:

- Implementing policies that level the playing field for low-emission technologies, enable access to clean power infrastructure and encourage scrap use
- Reducing production cost premiums through an increased number of low-emission projects
- Enabling shared infrastructure and supply chain stability through strategic partnerships.

8 Ammonia industry net-zero tracker

While increased production costs of blue and green ammonia remain a challenge, demand from newer sectors like shipping and power can be key for ammonia decarbonization.

Key emissions data[388, 389, 390]

1%
Contribution to global GHG emissions

0.46 $gtCO_2e$
Scope 1 and 2 emissions

2%
Emissions growth (2019-2022)

2.6 tCO_2
Emissions intensity (per tonne of ammonia, 2020)

97%
Fossil fuels in the fuel mix (2021)

3 times
Expected demand increase by 2050

<1%
Current low-emission production

2.2%
Reduced emission production

Readiness key takeaways

Technology
Clean hydrogen production is critical for ammonia decarbonization. The green premium for low-emission ammonia can vary from 40% to over 100%[391] depending on production route and region. Globally, steam methane reforming (SMR)/auto thermal reforming (ATR) with CCUS is cheaper.

Infrastructure
To meet the increase in demand, infrastructure investments of around $2.3 trillion are required.[392] The majority directed to increasing clean power capacities to 1,260 GW by 2050.[393]

Demand
Green premiums of 10-100%[394] will be difficult to absorb for fertilizer companies without policy support. Demand will be boosted by shipping, power and hydrogen carrier applications.

Policy
Policies for ammonia are emerging, particularly within the broader hydrogen landscape. Policies should focus on electrolyser manufacturing, CCUS implementation and regulatory frameworks.

Capital
1.5 times current investments required for decarbonization efforts. However, the business case remains weak, given 13% industry profit margin and 9% WACC.[397]

Stated energy transition goals

- The ammonia industry aims for a 27% emissions intensity reduction by 2030 and a 96% reduction by 2050. [395]
- 91%[396] of large publicly traded ammonia companies consider climate change in their decisions-making processes.

Emission focus areas for tracker

Ammonia emissions can be divided into two main categories:

1. **Energy-related emissions** primarily due to fossil fuel use to produce the required process heat and pressure for production of hydrogen.
2. **Process emissions** stem mainly from using fossil fuels as feedstock in the hydrogen production process.

Sector priorities

Exisiting assets

Reduce near-term emissions intensity by:

- Retrofitting existing fossil-fuel-based production with CCUS where access to CO_2 handling infrastructure is feasible
- Investing in CO_2 storage and transport to enable CCUS-based hydrogen production
- Adopting energy efficiency measures across existing plants.

Next generation assets

Accelerate technology and infrastructure development to drive absolute emissions reduction by:

- Investing in electrolyser plants to generate electrolysis-based green hydrogen
- Investing in sufficient clean power capacity, accelerating the maturity of methane pyrolysis and biomass gasification through pilots across lowest cost regions.

Ecosystem

De-risk capital investment to scale infrastructure capacity by:

- Investing in R&D to reduce costs, scale up the electrolyser capacity and the deployment of CCUS
- Supporting policies that stimulate demand from new applications
- Enabling infrastructure access through strategic partnerships.

9 Oil and gas industry net-zero tracker

Addressing methane and flaring emissions remain the key priority for the industry, but achieving net zero needs increased use of electrification and CCUS across the value chain.

Key emissions data[436,437, 438, 439]

15%	Contribution to global GHG emissions
5.1 $gtCO_2e$	Scope 1 and 2 emissions
-4%	Emissions growth (2018-2022)
90 $kgCO_2e$	Emissions intensity (emitted per barrel, 2022)
100%	Fossil fuels in the fuel mix (2019)
0.6 times	Expected demand increase by 2050
<1%	Current low-emission production
9-11%	Reduced emission production

Readiness key takeaways

Technology

Mature technologies like methane monitoring and mitigation, zero flaring, electrification and CCUS for gas processing face deployment limitations. Due in part to upfront costs, policy incentives, standards and infrastructure access. Low-emission refinery technologies are in early stages of development.

Infrastructure

Decarbonization of the oil and gas sector will need clean power generation capacity for electrification, CO_2 handling capacity for CCUS deployment at processing plants and refineries, and clean hydrogen generation capacity for refineries. Required investments are estimated to be up to c.$300 billion.[440]

Demand

Current green premiums remain below 10%,[441] but the market may switch to cost-competitive low-emission alternatives, particularly in developed economies.

Policy

Effective policies are vital, including incentives for low-emission tech, standards, taxation, flaring bans and R&D funding. Although major production areas have outlined emission targets, action plans and measurement, reporting and verification (MRV) guidelines, more effort is needed to turn these policies into practical, widely embraced initiatives.

Capital

The sector can invest in decarbonization by directing capital to low-emission technology, including methane reduction, electrification, CCUS and refinery transformation. Investments needed by 2050 could be up to $870 billion, about 4-6% of annual industry CapEx.[444] High levels of free cash flows could fund these investments.

Stated energy transition goals

– To align with net-zero ambitions, the industry aims for a 50% emissions intensity reduction by 2030 and 80% reduction by 2050.[442]
– 93% of large publicly traded oil and gas companies consider climate change in their decision-making processes.[443]

Emission focus areas for tracker

Oil and gas emissions can be divided into two main categories:

1. **Energy-related emissions** primarily due to energy consumption across the value chain.
2. **Process emissions** stem mainly from vented and fugitive methane emissions, gas flaring, transportation of crude oil, oil products and natural gas over long distances, and process emissions from refining.

Sector priorities

Exisiting assets

Reduce near-term emissions intensity from upstream and midstream operations by:

– Deploying available methane abatement and zero flaring technologies, supported by robust MRV standards
– Electrifying upstream and liquid natural gas (LNG) operations where feasible and enhance carbon capture gas processing
– Optimizing asset portfolios by directing capital allocation towards low-emission intensive assets.

Next generation assets

Accelerate downstream technology and infrastructure to drive absolute emissions reduction by:

– Deploying CCUS to capture carbon from rich CO_2 streams in refining
– Enabling access to clean hydrogen for heating and process application where refineries are co-located with clean hydrogen infrastructure
– Diversifying products – from traditional refining products to biofuels and synthetic fuels.

Ecosystem

De-risk investments to scale infrastructure capacity by:

– Using policy incentives for advanced technologies, while expanding access to existing infrastructure
– Progressing the technical maturity of low-emission refinery applications through R&D and pilot projects
– Deploying strategic partnerships to collaborate on technology advancement, infrastructure buildout and offtake agreements for low-emission products.

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