WE MEAN BUSINESS COALITION

CORPORATE CLIMATE STOCKTAKE 2023

Supported by: BAIN & COMPANY | RACE TO RESILIENCE | RACE TO ZERO

CONTEXT

BUSINESS TAKES STOCK

Business leaders around the world are trying to understand what a rapidly changing climate means for their company and industry, and what their role is in tackling the problem. Many are already leading the way in taking action to cut emissions. More than 13,000 companies have committed to cutting their emissions in half by 2030 through groups like the Science Based Targets initiative and the SME Climate Hub. Corporate procurement of renewable energy is rising faster than ever before. Yet is it enough? Is business moving fast enough to make an impact on global warming? And what about the potential of companies and markets to accelerate action, to influence government policies, and turbocharge the solutions that will deliver a sustainable, clean energy future for all?

At COP21 in 2015, with the negotiation of the landmark Paris Agreement, world leaders agreed that in 2023 they would take stock of their collective efforts to meet its goals. As nearly 200 nations prepare to meet in Dubai this year for COP28, the culmination of the first UNFCCC Global Stocktake represents a critical moment to course correct and to accelerate climate action where it is most needed. And as nation states are taking stock, so is business.

The Corporate Climate Stocktake (CCST) led by the We Mean Business Coalition and supported by the UN Climate Champions team and Bain & Company is the most ambitious, forward-looking review to date of private sector progress, obstacles and opportunities for achieving net zero. Each sector stocktake presents progress against international or national targets, and identifies the barriers faced by businesses that are rapidly decarbonizing to meet their climate targets.

INCORPORATING THE VOICE OF BUSINESSES AS WE COURSE CORRECT

The release of the Global Stocktake synthesis report in September 2023 confirmed what we already knew, "the world is not on track to meet the long-term goals of the Paris Agreement." Amongst a series of insights, the report finds, "achieving net zero CO_2 and GHG emissions requires systems transformations across all sectors and contexts, including scaling up renewable energy while phasing out all unabated fossil fuels, ending deforestation, reducing non-CO_2 emissions and implementing both supply- and demand-side measures." Ultimately, the GST concludes "much more action, on all fronts and by all actors, is needed now."

At one level, these conclusions acknowledge the limitations of the Paris Agreement. The transformation of our global economy into a net-zero emission system involves a series of technological transitions within economic sectors, with value chains spanning multiple countries. Intervention at the level of nation-states is therefore important but not sufficient. Sector transitions are kickstarted by innovation – with important national level support – but gain momentum as technologies progress along learning curves and diffuse across national boundaries. Here further acceleration relies on coordinated industrial policies and other cross-border policies. So while an international climate framework centered around targets and national emissions is important for setting the international direction of travel and ensuring transparency, it is not ideally suited to efficiently drive technological transitions within economic sectors. Equally, its report card – the Global Stocktake – is unlikely to capture the extent of the dynamism at the forefront of these transitions.

In contrast to the broad focus of the Global Stocktake, the Corporate Climate Stocktake takes a focused approach by examining the pace of clean solutions adoption within individual economic sectors and giving a clear voice to those operating at the frontier of clean energy innovation. For while it is true that nation-states are falling short of their climate goals, the pace at which clean energy technologies are being developed and deployed continues to exceed expectations.

The aim is to provide a forward-looking business perspective on the progress in transitioning the energy system away from fossil fuels and into clean solutions. Because understanding the pace of change within each sector and the specific systems barriers is at least as important as understanding the global state of climate action, and it's essential for informing our approach to course correction over the coming decade.

THE CORPORATE CLIMATE STOCKTAKE APPROACH

The CCST is based on surveys of 250 business leaders and detailed interviews with sector leading companies, industry experts, as well as an assessment of forward-looking indicators and corporate commitments. In total the exercise includes input from over 300 of the world's largest emitters and a data-based analysis of eight key transition sectors: power, road transport, concrete and cement, steel, shipping, agriculture, aviation, and hydrogen.

This report captures evidence from business leaders at the forefront of driving the change in their industries: to understand the pace of change in each sector, the barriers they are facing, and what our most ambitious companies need from governments to go faster. The approach in each sector is to examine the data available today that provides insight into the future; interviews and surveys with business give voice to the barriers frontier companies perceive across different segments or geographies; where possible case studies or examples are presented to demonstrate how business innovation and policy is enabling businesses to overcome barriers.

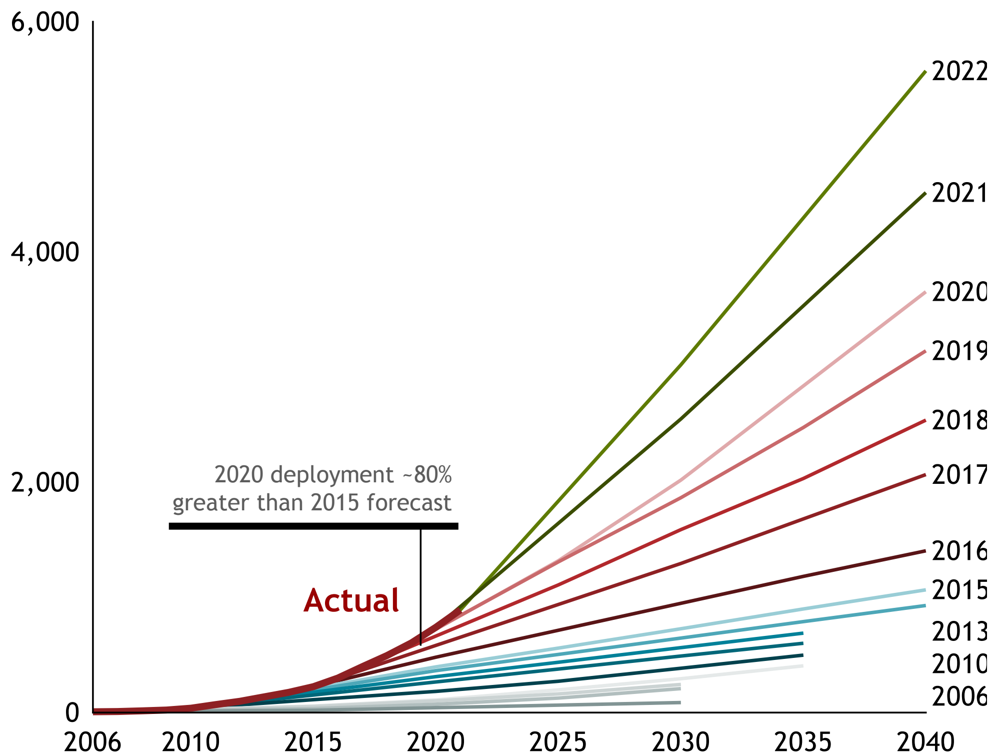
KEY FINDINGS: CROSSCUTTING THEMES

AN ACCELERATING PACE

The transition to clean technologies is accelerating. In some sectors the rates of investment are small scale, and there are only hints of early adoption of clean technologies. But in other sectors, where technologies are more mature, and market incentives and societal needs align, change is happening at an unprecedented pace and the rates of clean technology adoption have confounded expectations.

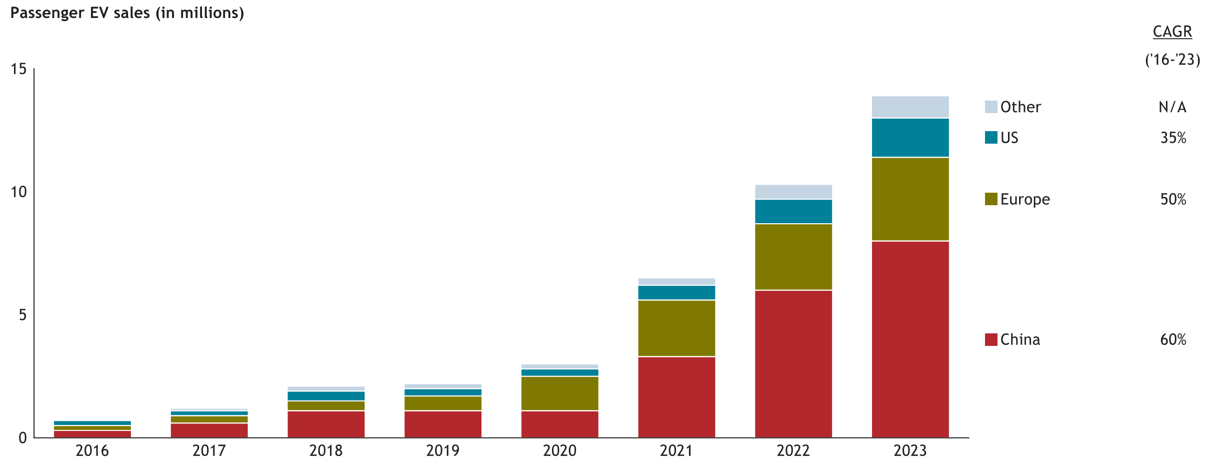
- In the power sector, the growth in renewable generation has consistently outpaced annual predictions. Solar and wind capacities deployed in 2020 surpassed projections made in 2015 by 80% and 20%, respectively. The two technologies are on exponential growth paths – accounting for over half of the net new generation capacity added since 2018, surging to 75% in 2021.
- In the road transport sector, EVs are taking off across vehicle types. In the past three years, global passenger EV sales grew by four times. The pace is set to increase with 100+ new EV models to be released by major manufacturers by 2026 as auto manufacturers commit to EV-only production and distribution platforms. The driving public may not yet feel it, but the sector has reached a "point of no return" to ICE vehicles.
- And in even in the harder to abate sectors, there are signs of non-linear change. An estimated 12M tons of Sustainable Aviation Fuel (SAF) production capacity is planned by 2030 – representing a 50 times ramp up from today. In steel, pioneering companies have eliminated the need for coal fired blast furnaces. The scale is still small – but the pace is what's exciting. Of the 83M tons of hydrogen-based production capacity in the pipeline for 2030, 66M tons was announced in the last two years.

Fig. 1. Global solar electricity generation capacity (GW)



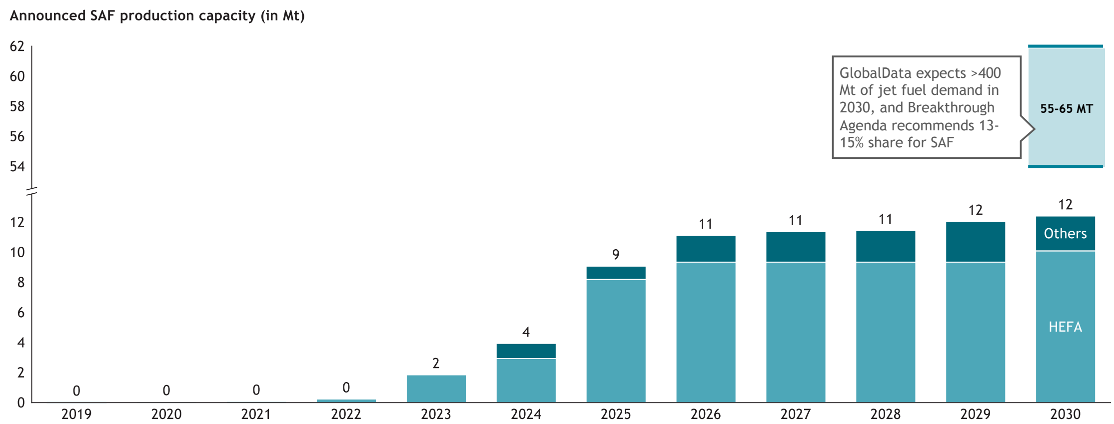
Note: 2010-18 new policies scenario; 2019-2022 stated policies scenario
Source: IEA World Energy Outlook 2006-22

Fig. 2. Passenger EV adoption is on an exponential growth trajectory, with China leading the way among developed EV markets



Source: IEA , Corporate interview

Fig. 3. Current announcements indicate SAF capacity will reach 12 Mt in 2030, but fall significantly short of Breakthrough Agenda's target range of 55-65 Mt

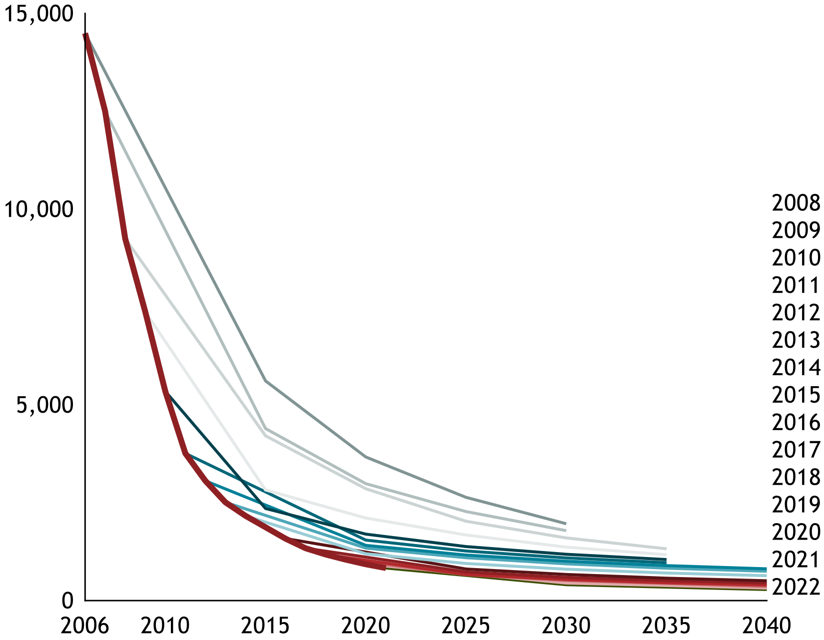


Note: Others include Gas to Liquid, Alcohol to Jet, and Power to Liquid; Assumes 100% of factory capacity will be utilized; Dashboard last updated in May 2023
Source: Sustainability Aerospace Together, Boeing; IEA; MPP; Breakthrough; Bloomberg NEF; GlobalData

Across all 8 sectors of the CCST, the evidence from business leaders and industry experts is striking. The rates of adoption of clean technologies are increasing, while costs are falling, as businesses invest in bringing new technologies down learning curves and up deployment curves.

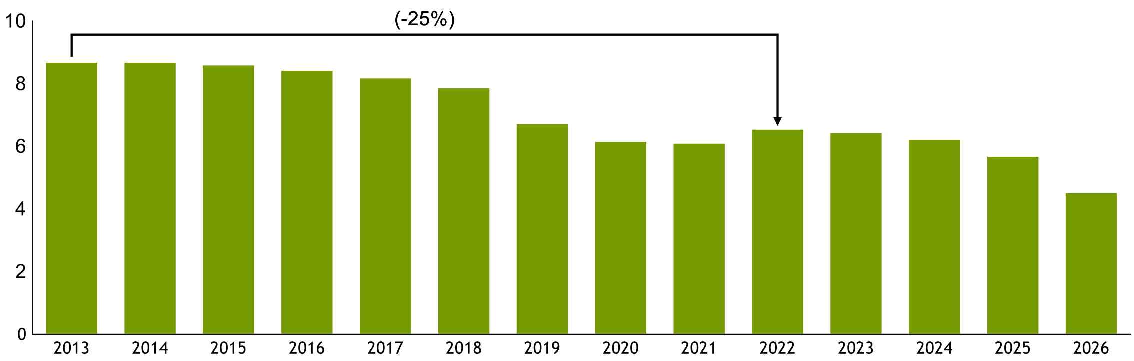
- Investment in renewable power has soared as capital costs for solar decreased by 85% in a decade, plummeting from $5,500/KW in 2010 to $830/KW by 2021
- Dramatic decreases in the costs of lithium-ion batteries have enabled the electrification of transport, decreasing by 25% from 2013 to 2022.
- Production costs for green hydrogen decreased by approximately 65% between 2010 and 2022. Industry anticipates costs will fall by another 45% by 2030 - as installed capacity for electrolyzers surges, driving capital expenditure down by 60% by 2030.

Fig. 4. Solar capital costs ($/kW)



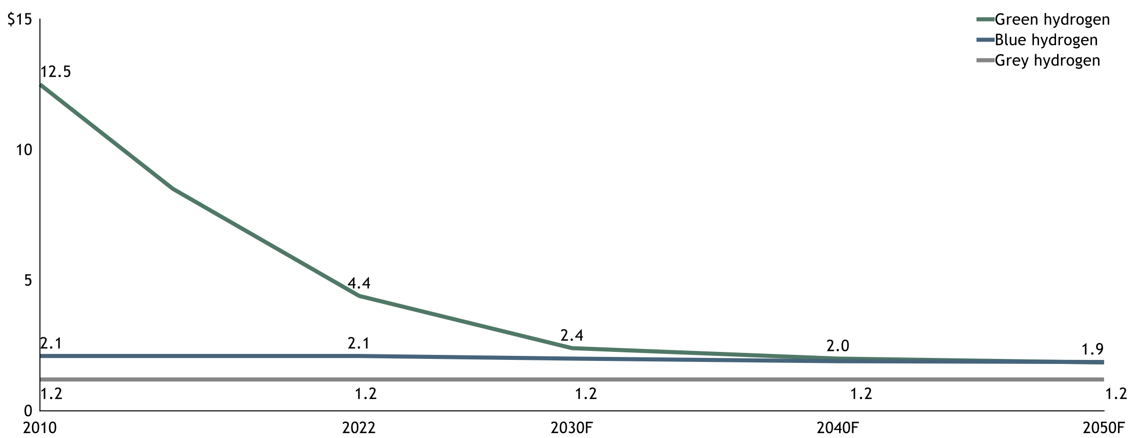
Note: Capital costs calculated using experience curve from IEA and IRENA dataset
Source: IEA World Energy Outlook 2006-22; IRENA 2019

Fig. 5. Cost for a 50 kWh battery in '000 euros



Source: P3/Bain battery cost model

Fig. 6. Global Levelized Cost of Hydrogen ($/kg)



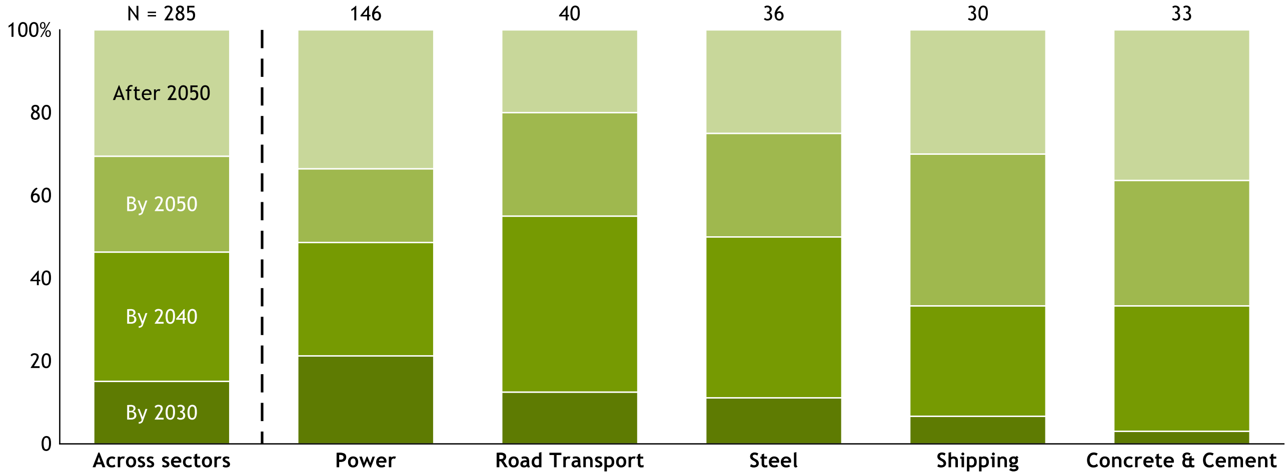
Note: Excludes impact of domestic subsidies, assumes no future change in carbon pricing or cost of natural gas (holds gas price constant going forward and historically at $6 / mmbtu to avoid gas price related volatility); curves based on consensus of estimates across various sources, but imply assumptions of roughly ~$45-$50 / MWh of electricity, 60-65% electrolyzer efficiency (varies across PEM & Alkaline), discount rate of 8% over a 20 year lifetime, with electrolyzer capex of ~$900-$1100 / kWe (varies across PEM & Alkaline)
Source: Bain analysis

KEY FINDINGS: SYSTEM CONSTRAINTS

While those at the forefront of transition point to an acceleration, overall, business leaders remain concerned about the progress of the transition. Under current conditions, over 30% of those surveyed conclude that their company will still be reliant on fossil fuels into the 2050s. This is despite many having set net zero targets well ahead of this date. In every sector, business leaders point to a range of transition barriers which are holding them back – from the availability of infrastructure to the realities of commercial incentives:

- **Infrastructure:** In shipping, the lack of infrastructure to support fuel production and bunkering is among the top 3 concerns of surveyed leaders. Commercial constraints and uncertainty surrounding technology pathways (hydrogen, methanol, or ammonia) increases deployment risk.
- **Consumer behavior:** EV technologies have advanced tremendously in terms of range and cost parity with ICE vehicles, but consumer concerns persist. Higher upfront costs, range anxiety and negative perceptions around refueling experiences all continue to slow down wider adoption.
- **Market structure:** In steel, zero-carbon technology has achieved commercial scale, but costs are 20% higher than conventional methods. Businesses do not anticipate cost parity with traditional blast furnace production any time soon, complicating large-scale deployment in this globally competitive sector, particularly as most new capacity is anticipated in emerging markets.
- **Technology:** Sustainable aviation fuel (SAF) is the only near-term solution to decarbonize aviation, and aircraft manufacturers are planning to make engines 100%-SAF ready as soon as 2030. A further ramp up in low carbon fuels will be needed to hit aspired 2030 production levels of 56-65 Mt; planned production capacity is currently only at 12 Mt. But established biofuel technology faces feedstock constraints, and significant investment will be required to ensure alternative emergent technologies reach maturity.
- **Availability of inputs:** In cement, the road to full decarbonization is dependent on the availability of low carbon clinker substitutes. Blast furnace slag and fly ash are well known substitutes; however, their future availability might become limited in certain geographies where steel and coal production decarbonize. Producers must turn to other alternatives - calcined clays, ground limestone, and alternative pozzolans - and figure out how to feed them into design and construction in a way that is commercially viable.
- **Business model:** In many cases, currently adopted business models make transition to net-zero products and services challenging. For example, while peak deforestation may be behind us, demand and prices for beef, palm oil, and soy continue to rise, representing powerful economic drivers for land use change. Without greater incentives for landowners and farmers to preserve or reforest lands, the business case remains challenging.
- **Workforce:** The power industry faces workforce challenges. 30% of industry leaders surveyed believe they have the workforce that can meet net-zero aligned generation and transmission and distribution goals. Reskilling can be crucial for enabling system operators to build confidence in integrating greater levels of variable generation into traditional thermal power systems, and without reskilling the potential job losses in legacy power plants can create significant political and social constraints.

Fig. 7. When decision-makers were asked when they expect their organizations or sectors to transition away from fossil fuels entirely, they said...



Note: Survey question - Projecting the trajectory of your company's clean transition, in approximately what year do you estimate your company will no longer procure fossil fuels for <sector-specific use case>?; Chart excludes 7 hydrogen respondents.
Source: Bain / WMBC Corporate Climate Stocktake Survey (N = 215)

KEY FINDINGS: BREAKING THROUGH BARRIERS

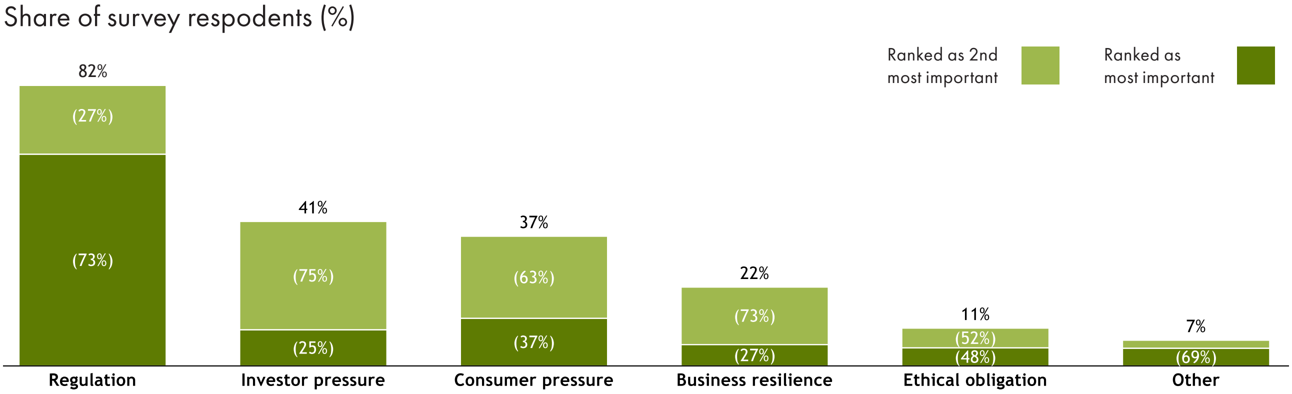
For every transition barrier, there are leading businesses taking action to breakthrough. The Corporate Climate Stocktake also showcases the extraordinary innovation that many of these companies are employing to drive forward the transition, whether through the development of new technology or business models.

- In power, companies are not waiting for regulators to improve system integration and cut interconnections queues. **EDP,** a leading Portuguese power company, is focusing on hybrid projects that combine wind and solar, coupled with storage to smooth the variability of generation. Meanwhile, startups like US-based **Form Energy** are addressing intermittency issues through the development of lower cost iron-air batteries that promise to be ten times cheaper and less vulnerable to resource constraints than lithium-ion technology.
- Car manufacturers are directly tackling customer frustration over charging infrastructure. **Mercedes-Benz, BMW, Daimler, Ford, Volkswagen** and latterly **Hyundai** are jointly investing in charging stations through the JV IONITY. While in freight, **Amazon** is collaborating with utilities and innovative startups to set up charging stations at their facilities, including warehouses and delivery hubs, facilitating the rollout of their emerging EV fleet.
- With its bold commitments to decarbonization, **Volvo Group** has changed market dynamics for green steel. Through their strategic alliances major steel producer **SSAB** and **Volvo Group** are commercializing the world's first vehicles to be made of fossil-free steel. Volvo plans already to start the production of concept vehicles and components from green **SSAB** steel this year.
- In the aviation industry, companies across the value chain are breaking new ground. **Neste,** a biofuel refiner is broadening its SAF production, enhancing the accessibility of essential components such as animal fats and used cooking oils through a global sourcing platform. Startups, **ZeroAvia** and **Northvolt**, are exploring alternative propulsion to address anticipated SAF bottlenecks; while **HIF** and **OxCCU** are advancing e-fuel technologies. Meanwhile **CFM** is pioneering open-fan engines, targeting a 20% reduction in fuel usage; and **Google** and **American Airlines** are using AI to reduce contrails and related GHG emissions.
- Chemical and energy majors including **BASF, Solvay, Nel** and **ITM** are developing a new green hydrogen economy through the development of such as alkaline electrolysis, PEM, and methane pyrolysis. Others are focused on building the hydrogen infrastructure, such as **GHI,** a US startup plans which plans to provide hydrogen storage using salt caverns.
- In the shipping industry, **Maersk** has leapt ahead of global regulatory requirements though a commitment to procure only vessels compatible with zero-emission fuels as well as retrofitting the existing fleet. This is set to drive the development of new green methanol supply chains as they develop extensive off-take partnerships with energy companies.
- Leading cement manufacturers have become material science laboratories, building multi-million-dollar facilities dedicated to production of alternative cement and concrete mixes. These mixes use novel supplementary cementitious materials (SCMs), such as limestone and calcined clays used in novel LC3 mixes, with the goal of reducing emissions intensity of cement and concrete production by ~50%.
- In the agriculture industry, enterprise players like **Nestle** and **DSM** as well as startups like **ZELP, Future Feed, Blue Ocean Barns, Volta Greentech, Elanco**, and **Mootral** are investing in curbing on-farm livestock emissions including the use of innovative new feed additives, novel immunological approaches, and wearable technology to reduce methane emissions from cattle.

KEY FINDINGS:
THE INVISIBLE HAND OF THE MARKET OR THE STRONG ARM OF THE STATE

Government support is playing an instrumental role in enabling companies to transition. Over 70% of companies surveyed identified government regulation as being the most important driver for accelerating the energy transition, ranking it significantly higher than consumer pressure at 37% and investor pressure at 25%:

Fig. 8. When decision-makers were asked to rank the following six drivers on their importance to accelerating action for the energy transition, they said...



Note: Survey question - What are the key drivers to accelerated action for the energy transition? Please rank the following:
Source: Bain / WMBC Corporate Climate Stocktake Survey (N = 215)

- The green hydrogen industry has been kickstarted by government intervention. Over 40 nations have launched hydrogen strategies, but it is the EU's Green Deal that is creating essential demand signals through agreements to transition 30% of EU steel to green, blending mandates for synthetic aviation fuels, and ambitious targets for green hydrogen use industry processes - all by 2030. EU Member States have jointly pledged about €30B to fund green hydrogen projects, targeting a cumulative 60 GW of electrolyzer capacity by 2030. The United States has joined the effort with the launch of $7B for 7 Hydrogen Hubs across the country and plans for $1B of demand side support.

- Emerging markets in the Global South, including India, Thailand, and Mexico, are proactively driving the transition to electric vehicles. Their strategies combine demand-driven policies, such as tax incentives to promote EVs over ICE vehicles, production support policies to expand local battery manufacturing, as well as electrification programs for public transportation. These countries are also investing in charging infrastructure as well as leading the way on battery-swapping technologies to support a growing market for smaller EVs and electric scooters.

- The EU has demonstrated the ability of governments to create market conditions that make otherwise commercially inviable technologies viable. In the concrete and cement sector, CCUS is currently a prohibitively expensive technology for producers to install and operate. The EU's ETS cap-and-trade system increases prices on carbon, progressively decreasing carbon allowances and increasing the competitivity of CCUS, with the associated CBAM to enforce a carbon price. Further, financial support in the form of the €20B EU Innovation Fund, €20B Connecting Europe Initiative, and the €2B Just Transition Scheme all create opportunities for producers to install and operate CCUS-enabled facilities.

Most businesses welcome new supportive regulation that levels the playing field or provides support for the development of low carbon technologies. However, some businesses also expressed concern over the pace and scope of regulatory intervention, particularly the legal burden imposed by circularity, supply chain and disclosure regulations in the EU. One business leader described the risk that sustainability was being turned from a leadership opportunity to a compliance issue, which risked sapping business innovation.

KEY FINDINGS: COMMERCIAL REALITY

While we can be cautiously optimistic about the pace of transition in some sectors, even ambitious companies at the forefront of innovation are struggling to meet science-based targets. For many, accelerating clean energy investment runs up against market fundamentals – there is a limit to the scale and size of the green premium available for low carbon steel, cement, and sustainable aviation fuel. For others, they simply cannot transition absent wider changes to their market environment – even large companies can have limited leverage over their suppliers when they are minority players in hard to abate value chains.

In some cases, climate policy frameworks are also failing to incentivize companies to focus on the right issues. For example, the world needs major international finance institutions to invest in transitioning away from high carbon assets. Institutions are responding, with some banks announcing funds for clean energy financing. However, in a world where the metric is the carbon content of your balance sheet, large banks are not encouraged to increase exposure to coal fired power assets even if the aim is to de-coal the system. In other cases, major companies can appear to make greater progress against targets divesting higher carbon customer segments rather than transitioning them, or by monopolizing access to low carbon supply chains rather than investing in developing them. There is no simple answer to these issues, but the most ambitious companies are increasingly thinking about system and sector transition not enterprise decarbonization, whether that's **Google**'s 24/7 procurement initiative, **Amazon**'s commitment to enabling the deployment of zero carbon vessels or **Enel**'s school of power regulation.

Despite the evidently systemic nature of the transition challenge, the pressure at enterprise level is intensifying. Many investor groups, consumers, and governments are demanding transparency, ambitious targets, and tangible actions towards carbon reduction. Those in the highest emitting sectors, feel this pressure most acutely. But few will say publicly what many acknowledge privately- the business case for low carbon investment is sometimes challenging. Many would like to see more government intervention to level the playing field. Society needs businesses leaders to take risks, drive innovation and transform their industries. But in the case of climate, governments also need them to get much louder and more precise about what is needed for individual sectors to accelerate the transition.

> "By placing the responsibility on businesses to reconcile the tension between climate action and commercial interests, we are asking for failure.
>
> – Katherine Dixon, Partner, Bain & Company

REALLY TAKING STOCK

LEARNING THE RIGHT LESSONS

The Paris Agreement has been catalytic for global climate action. Over 90% of the world›s economic output is now covered by some form of net-zero targets, governments around the world are pursuing policies to reduce fossil fuel usage, climate finance has at least increased. But is this enough?

Since 2015, our experience of the dynamics surrounding clean technology transitions has deepened significantly. Sectors are at different stages of transition but there are common patterns. Where innovative business leaders have accessed cheap capital or government support to develop cleaner technologies, and policy and voluntary demand has enabled the creation of markets, clean tech has scaled up, and costs have come down, driving a positive feedback loop that accelerates change. It is the interplay of business innovation, industrial policy, and availability of capital - not emissions targets - that will determine the shape of our future energy system.

If we are serious about taking stock of our progress at COP28, we need to ask not only whether we are doing enough but whether we are organized effectively to increase the dynamic efficiency of transitions. Dynamic efficiency means a focus on coordinated action to drive the development and diffusion of clean technologies across markets rather than optimizing the allocative efficiency of emissions reduction across nations given the technologies we have today. This means moving towards multilateral coordination of industrial policy.

To do this, we need to capitalize on the strong international process of the UNFCCC and Paris Agreement, including the trusted multilateral discussion forum it brings, and use forge new, strategic ways of working for strategic sectors. Sectoral approaches cannot be merely a complementary feature of the international climate process – they must be integrated with it.

A FOCUS ON ACCELERATING DEMAND FOR CLEAN SOLUTIONS SECTOR-BY-SECTOR

- Sectoral approaches cannot be a secondary consideration in the international climate process. Businesses, investors, NGOs, and governments need to work together intensively, sector by sector, to define rapid and realistic decarbonization pathways that leverage demand signals.
- This implies genuine whole-of-government approaches to climate, with different ministries becoming involved in climate change negotiations. Governments need to implement strong, sector- specific strategies to create demand for zero carbon solutions.
- We know what is needed to accelerate the clean energy revolution – we now need to replicate this across geographies through sector-specific strategies in which governments go beyond target and economy wide carbon pricing to directly support the development and deployment of clean technologies.

SYSTEMATIC COLLABORATION BETWEEN BUSINESS AND GOVERNMENT TO OVERCOME TRANSITION BARRIERS

- The building blocks of collaborative approaches exist within several of the major demand sectors that currently rely on fossil fuels. In some sectors, business is organizing to overcome the barriers to decarbonization – infrastructure, access to inputs, commercialization, regulation, and technology, etc.
- For the transition to happen at the scale and pace required, both public and private sectors need to invest in the transition. This requires much more systematic collaboration between business and government. Where this is happening, the transition is gathering pace.

- But more action is needed. The process of understanding where technology development is headed, identifying the barriers, and setting out what will enable business to direct capital flows where they are most needed, is necessary to rapidly drive adoption of clean technologies.

INTERNATIONAL COORDINATION

- International cooperation is essential, but it does not always need agreement across all nations. In many sectors of the economy, sectoral institutions are often too big to function effectively. We do not need more grand alliances around the goals of net zero nor necessarily big-ticket multilateral diplomacy; instead what we need is the painstaking pragmatism of smaller groups of governments and businesses willing and able to advance change.
- For globally integrated industries, technology options for decarbonization exist, but international competition is slowing adoption. Business and governments may understand what policy and investment decisions are needed, but they often face difficult choices: either risking the loss of industry or facing a rising tax burden from industrial subsidies. The result in these cases is stubborn investment patterns; technology is not getting cheaper, and demand for low-carbon choices is increasing at a slow rate.
- Transition will only happen at the pace the world needs with effective international coordination. When learning is shared, and when actions are coordinated to accelerate innovation and the diffusion of technologies through global markets, including through common international standards, industries can move rapidly. Governments need to come together to support industry in making this transition – not only in multilateral format but also by sectors – to play the coordinating role that only governments can.

> "The Global Stocktake is the only mechanism we have to pause and reflect on whether our collective efforts are sufficient for achieving the critical goals of the Paris Agreement. We cannot afford to miss this opportunity by asking the wrong questions."
>
> – Maria Mendiluce, CEO, We Mean Business Coalition

As global leaders gather to review national progress and revisit climate ambition, we need to ask whether the set of mechanisms and institutions we have is adequately equipped to facilitate the transformation implied by our climate objectives. The system of national goals negotiated through the UNFCCC is the foundation of our collective response to climate change. But this foundation is insufficient. Transitioning our global economy requires a major leap forward in international energy governance. An effective sectoral framework supported by strengthened multilateralism is needed to tackle this underlying international coordination problem in the hardest-to-abate sectors. Creating the right incentives means working in small groups, in tightly defined sectors, and across industry and government boundaries. We need to think creatively about how we enable change.

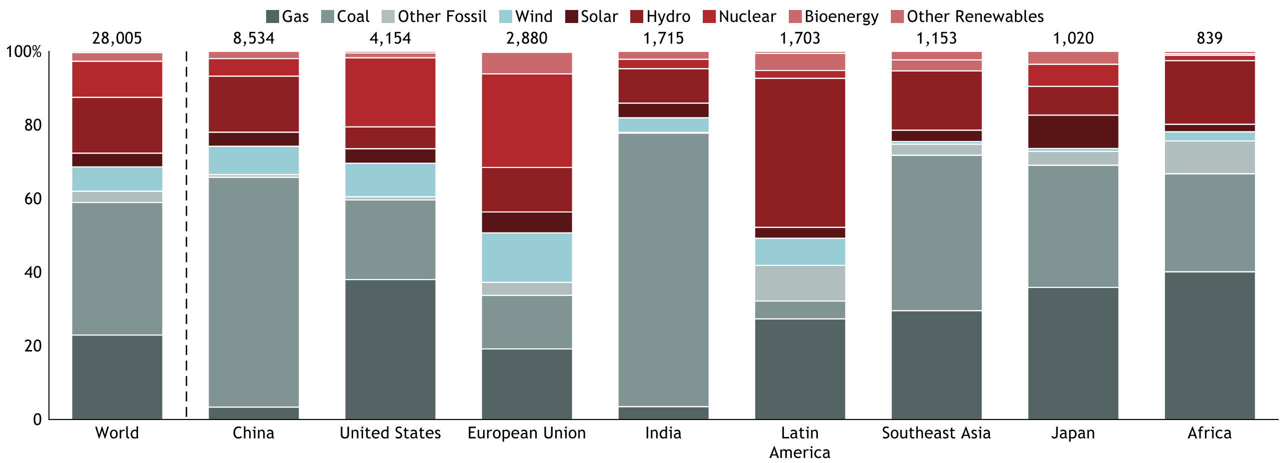
SECTOR SUMMARIES: POWER

Four major economies - China, US, EU, and India - set the pace of global power decarbonization, with 61% of global power generation. In total, clean electricity represents ~27% of global generation. But it's growing rapidly, with investment in renewables outstripping fossil fuel generation. Yet emissions are still rising, as new coal capacity continues to be added. The growth in power demand in developing markets will determine the shape of the future's power sector. In many countries, market and non-market barriers are holding back private sector investment in cheaper renewable power generation. A step change in international coordination, which focusses on policy and market design, not targets, would enable learning to be shared, support the development of more integrated power markets, and lower the cost of capital.

INTEGRATING HIGHER LEVELS OF RENEWABLES IN DEVELOPED MARKETS

Planned clean capacity additions in developed markets like the EU and US are nearing 2030 targets. But business leaders say regulatory procedures and T&D constraints are deterring investment.

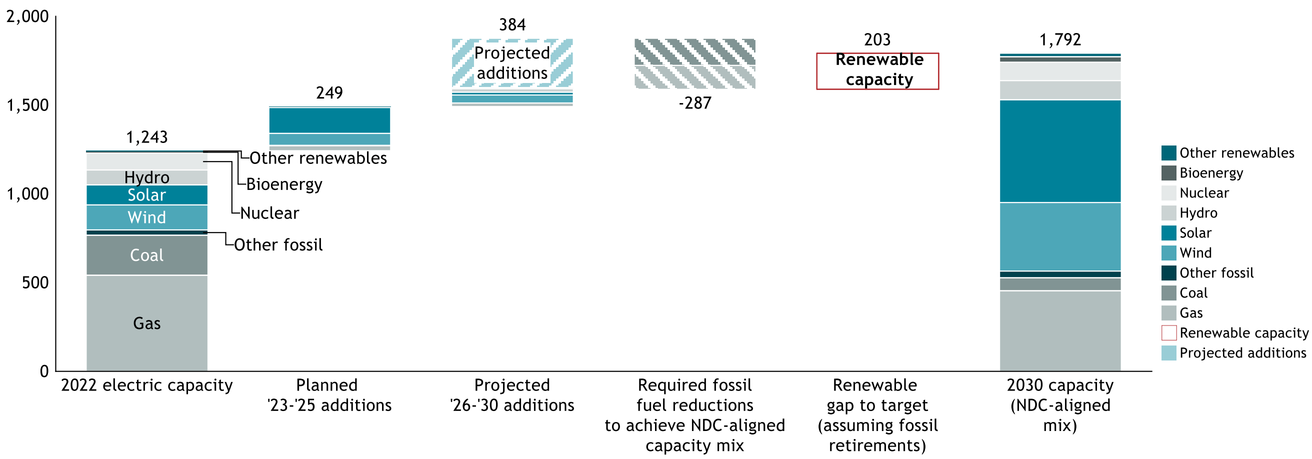
Fig. 9. Annual power generation by source (TWh, 2021)



Note: Latin includes Mexico, Central America, South America, and the Caribbean; Southeast Asia includes Philippines, Indonesia, Vietnam, Malaysia, Thailand, Myanmar, Laos, Cambodia, Singapore, Brunei.
Source: Ember EleAmericactricity Data Explorer

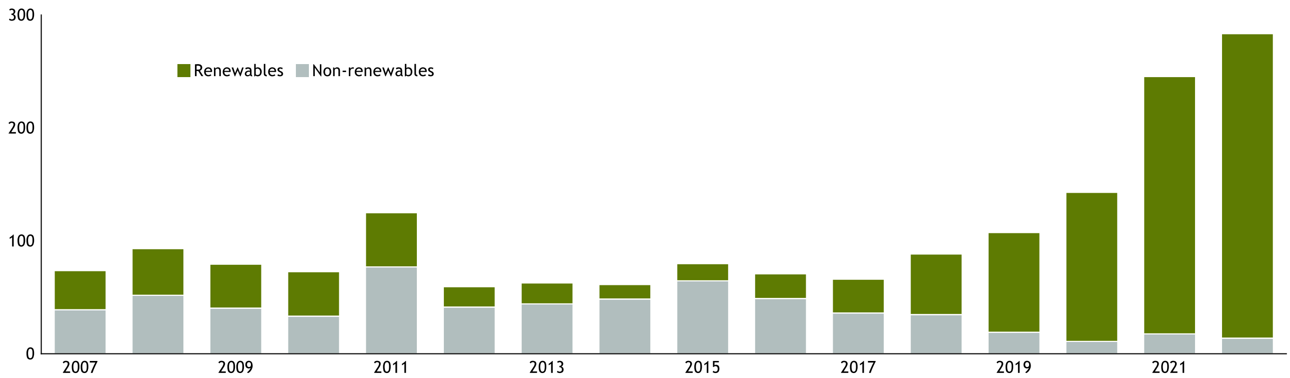
- In the US, developers face significant uncertainty as renewable generation capacity is backed up in interconnection queues, while the fragmentation of US power markets limits the potential to integrate more renewables investment.
- The EU's single electricity market supports an accelerated transition, but permitting delays are frustrating investment, and business is concerned about how grid flexibility will be incentivized

Fig. 10. Electric capacity by source (GW, U.S.)



Source: Ember - Yearly Electricity Data (Capacity data aggregated from Global Energy Monitor, Global Data - Upcoming Power Plants; IEA – Global Energy and Climate (GEC) APS Model; UN Intergovernmental Panel on Climate Change – Average Life-cycle CO2 equivalent emissions; EIA – Carbon Intensity of Natural gas, Berkeley Lab Electricity Markets & Policy – Interconnection queue capacity

Fig. 11. PJM interconnection queue (GW)



Source: Berkeley Lab Electricity Markets & Policy; JP Morgan 2023 eye on the market

Transitioning legacy thermal coal

Renewable capacity additions are growing strongly in parts of Asia, but this is not leading to thermal coal plants being retired. In these regions, business leaders point to the availability of financing as the top barrier to decarbonization; with market participants in regions with significant coal generation lacking confidence in the ability to meet both generation and transmission capacity. Across Asia, the pipeline of planned thermal capacity additions is sizeable – baking in significant growth of power sector emissions over the next decade.

- China is setting the global pace in deploying new renewable generation capacity, but despite this, new coal capacity is still set to come online.
- India has a large volume of clean capacity additions in the pipeline, but fossil-dependent capacity is likely to be retained to meet growing energy demand.
- In Southeast Asia more than 70% of planned capacity is fossil dependent.

Fig. 12. Share of installed coal plant capacity planned for retirement (GW)

Source: Global Coal Plant Tracker, Global Energy Monitor, January 2023 release

Leap-frogging fossil in growing power markets

In many parts of the world electricity demand outstrips supply. In Latin America rapid growth has been largely met through renewable generation. This has been driven by strong foreign direct investment (FDI), with concessional finance increasing confidence of private investors. Uruguay has been particularly successful in leveraging natural resources and is now set to become a power exporter. This phenomenal success story will need to be replicated in developing economies if the world's growing demand for electricity is to be met through clean technologies.

Power: Policy opportunities for accelerating the transition

The power transition is well underway in many markets, driven by the underlying economics of low-cost renewables. But there remain significant barriers to investment. Given the length of asset lifetimes, ensuring consistent market frameworks, the bankability of projects, and reducing non-market barriers such as permitting are essential to enable the next wave of renewables build out. Fortunately, public-private coordination and international collaboration is improving, but progress is uneven.

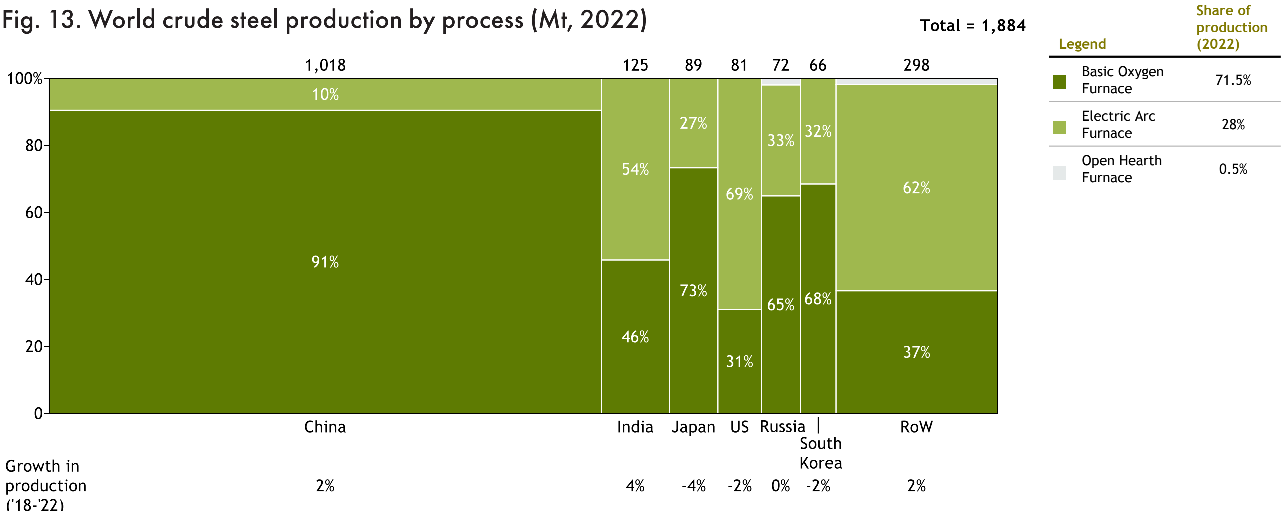
In developed markets, governments need to work together to more rapidly resolve structural market issues and supply chain bottlenecks – such as the wind industry is currently facing; to better integrate markets across borders; and to consider the broader incentives on capital flows. They also need to focus on accelerating permitting processes, including critically for power transmission and distribution projects.

In the Global South, country platforms under the Just Energy Transition Partnership (JETP) model have enabled a step change in technical assistance in several countries, including through bringing together policy expertise and finance, and focusing on workforce transitions. But more political will is needed to make the hard reforms required – whether that's managing the financial and social implications of retiring legacy coal assets, including many young plants; addressing vested interests; or changing incentives around transition finance.

SECTOR SUMMARIES: STEEL

Steel production has increased steadily over the last decade, with the average carbon intensity of a ton of steel also slightly increasing, despite technology improvements. Recent acceleration in investment in zero emission steel production demonstrates growing confidence in novel steel technology. But more than 70% of global steel is produced using high-emission technology – a trend which is set to increase. Leaders in the steel sector identify availability of inputs as the primary barrier to decarbonizing along with technical feasibility, commercial viability, and infrastructure. But with blast furnace technology still set to dominate future production, coordinated international action will be required to enable the build out of new low carbon steel capacity at scale or the abatement of legacy technology.

Fig. 13. World crude steel production by process (Mt, 2022)



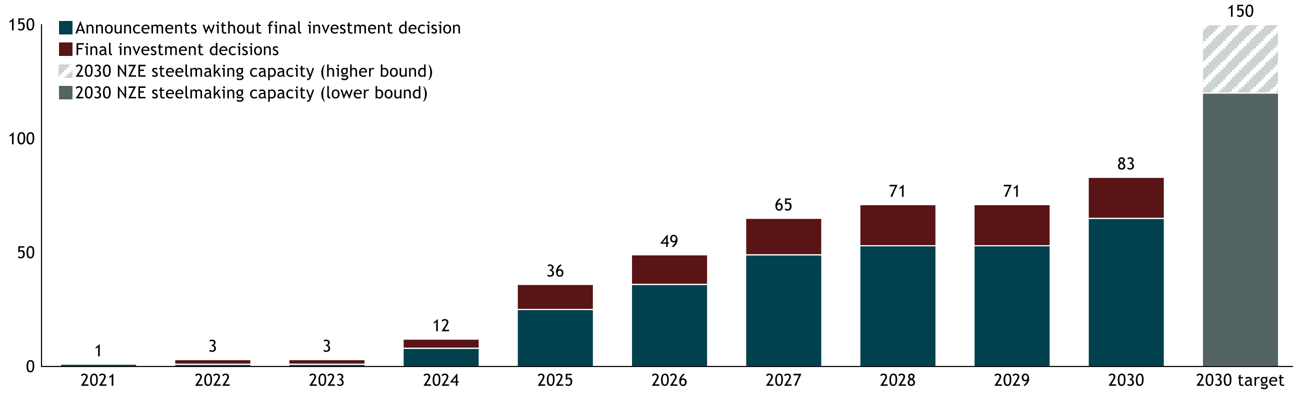
Note: Global production includes both primary and secondary steel production volumes.
Source: World Steel Association, World Steel in Figures 2023.

Embracing near-zero emission technology

Hydrogen based ironmaking, known as Direct Reduction of Iron with hydrogen (DRI H2) is a new technology with near-zero emissions (assuming the hydrogen used is green hydrogen); investment in plants is now beginning. Electric arc furnace (EAF) production – which can be low-emission depending on the source of electricity is a proven technology and investment in capacity is accelerating:

- ~75% of business leaders from the U.S., Canada, and Europe (where scrap steel used in EAF production is more widely available compared to for example India) believe that their companies can completely shift away from blast furnace production into electric arc furnace production by 2050; and of the 83M tons of H-DRI-EAF steel production capacity announced to come online by 2030, 66M tons was announced in the last two years – mostly in Europe.
- But H2-DRI production costs remain over 20% higher than conventional, highly-emitting blast furnace-basic oxygen furnace (BF-BOF) production. Although costs will come down as green hydrogen technology scales, near zero emission steel is unlikely to reach cost parity with BF-BOF steel.
- While European governments are incentivizing the deployment of green steel, new capacity will predominantly emerge in countries from the Middle East, North Africa and Asia; in India, the world›s second largest steel producer, the majority of capacity under development relies on blast furnace technology.

Fig. 14. Global near-zero emission primary steelmaking capacity (Million tonnes p.a.)



Note: Title quote from Environment Manager, Auto manufacturer #2; The 2030 targets refer to the near-zero emissions primary steelmaking capacity that would be needed to be on a 1.5C compatible pathway based on IEA, IRENA, UN 2022, and Agora Industry scenarios.
Source: Agora Industry (2023); Global Steel Transformation Tracker (2023)

Ensuring availability of inputs

Availability of key inputs is a key constraint for near-zero emission steel production - such as scrap, high-grade iron ore, and green hydrogen – but the situation is improving:

- All the major steel consuming nations are promoting scrap utilization - China's supply of steel scrap is expected to nearly double by 2030 which has supported the expansion of electric arc furnace capacity across the country.
- For DRI, the supply of green hydrogen is the most immediate input constraint – requiring also good availability of green power – but in the longer term the availability of high-grade iron ore will likely serve as a hard limit on the scaled deployment of near zero emissions technology.

Abating emissions from existing production

The growing demand for steel in emerging markets looks set to lock-in high carbon capacity for many years to come. According to Global Energy Monitor, India has close to 200M tons of steelmaking capacity under development, around 150M tons of which through the highly-emitting BF-BOF technology. Without swift intervention to incentivize alternative technologies, carbon capture, utilization, and storage (CCUS) will likely be the only route to drive decarbonization over the longer term, which in turn would require a dramatic shift in the regulatory landscape to drive adoption.

Steel: Policy opportunities for accelerating the transition

Decisive action from governments in advanced economies, emerging markets and developing economies will be needed to ensure the next series of capacity additions and replacement for steel that is at least lower carbon and where possible zero carbon. Achieving this will require stronger international coordination and support, given the challenges inherent in such a competitive and strategic sector, as well as in-country policies.

One element is to encourage early-stage adoption of net zero steel production within countries, including by policies to compensate for higher production costs (such as carbon contracts for difference) and by stimulating demand whether through public procurement or incentives to encourage private sector procurement.

Yet scaling will likely require greater cross-border market intervention across the major economies, creating a strong case for an international agreement. Such an agreement might include the alignment of regulation and standards of steel production, technology transfer mechanisms, and international support for the adoption of lower carbon production methods. In the interim, developing and agreeing international standards for the certification of lower carbon steel will be important for enabling international trade in green steel and giving confidence to potential corporate buyers.

SECTOR SUMMARIES: AVIATION

Aviation represents 2% of global greenhouse gas emissions, against a backdrop of rising demand for air travel. The aviation industry has committed to reaching net zero carbon emissions by 2050 but faces significant challenges in developing and adopting sustainable aviation fuel (SAF) at the pace required. Some governments are driving the uptake of sustainable aviation fuels through mandates. But stronger international coordination is needed to accelerate the production and adoption of SAF at scale, optimize the resulting emissions reductions, and ensure a level playing field.

Ramping up low-carbon fuel supply

Sustainable aviation fuel is the only near-term solution to decarbonize aviation and aircraft manufacturers are planning to make engines 100%-SAF ready as soon as 2030.

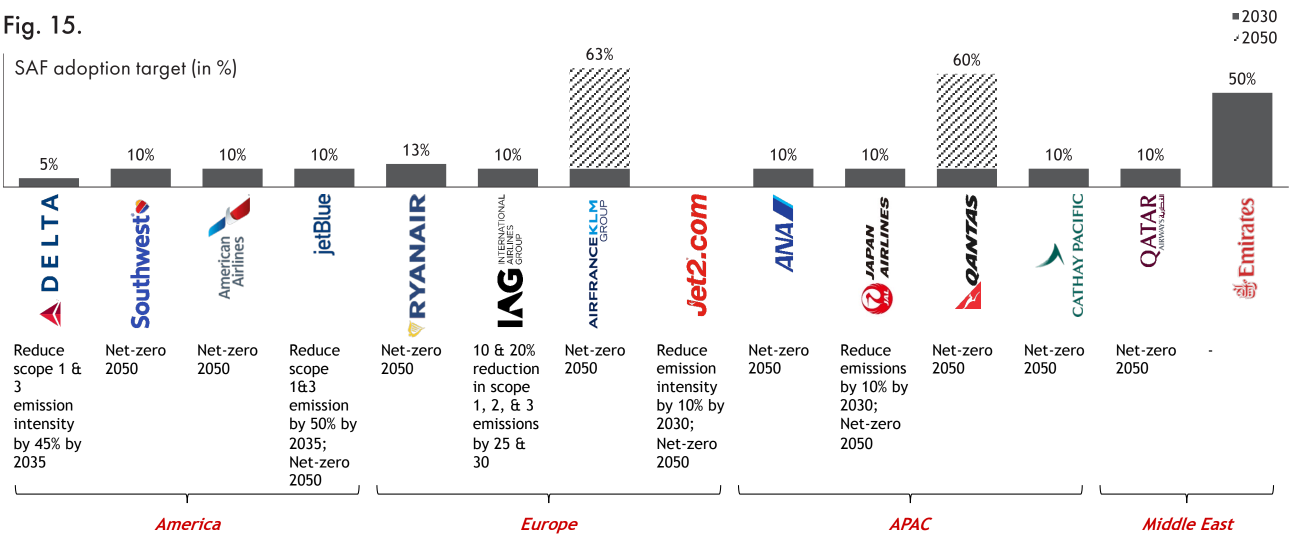
- SAF supply is accelerating. An estimated 12 MT of production is planned by 2030, representing a 50 times ramp up from today, with the majority coming from the HEFA pathway (conversion of vegetable oils).
- But production capacity is still set to fall short of 2030 ambitions, given feedstock constraints within existing SAF pathways.
- Scalable long-term solutions such as synthetic fuels are some distance from maturity and will require continued support to drive the large investments needed to bring to commercial scale.

Driving low-carbon fuel adoption

Alongside regulatory mandates, voluntary demand is playing an important role in driving adoption. Many airlines have put in place ambitious blend targets, with 100 airlines already signing a commitment to use 10% SAF by 2030. The US and EU have implemented strong policies to incentivize the production and usage of SAF, including niche demand for e-fuels.

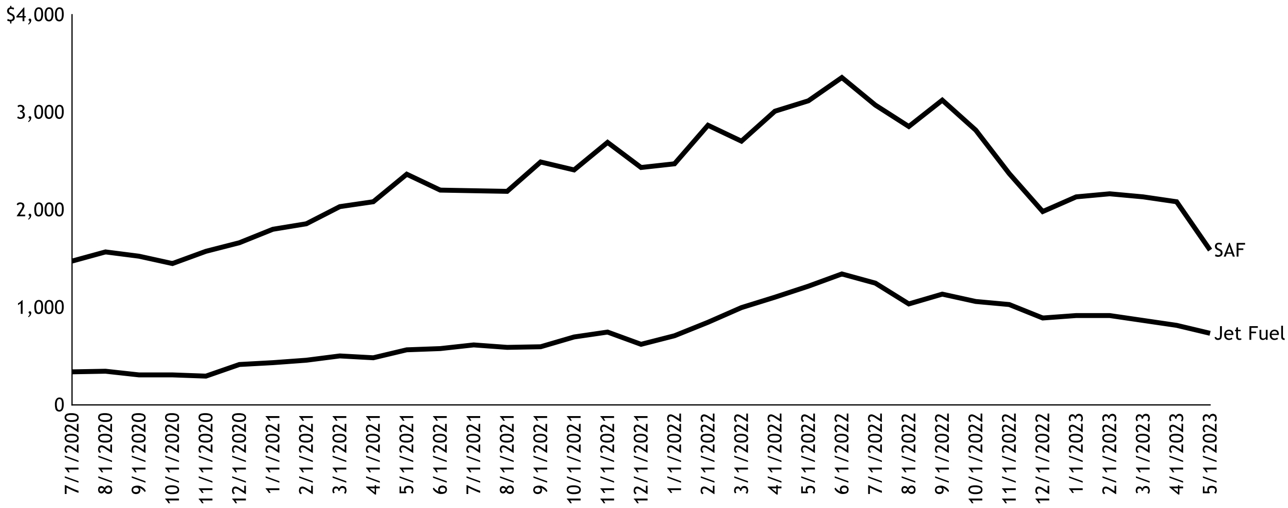
Although cost reductions are expected as technologies come down learning curves, SAF at scale will likely still demand a sizeable cost premium well into the 2030s. This will constrain growth in voluntary demand given fuel costs comprise 25-30% of airline operating cost. Internationally coordinated fuel mandates, accompanied by supply side policies to support the development and optimization of production is likely to be needed to drive SAF adoption at scale.

Fig. 15.



Source: Credit Suisse March 2023

Fig. 16. Price of sustainable aviation fuel vs. jet fuel (in $)



Note: SAF pricing is based fuel delivered to the Northwest Europe.
Source: JP Morgan (Novemboner 2022), S&P Global Platts, Bloomberg Finance L.P. (May 2023)

Optimizing well-to-wake energy efficiency

Beyond the development and adoption of SAF, optimizing well-to-wake energy efficiency is critical to aviation›s decarbonization journey. Some modern aircraft are already 15-20% more efficient than the global average. The industry has historically achieved a consistent 1-2% annual improvement in fuel burn over decades, but surpassing this benchmark is challenging. Achieving higher efficiency globally may necessitate international support and cooperation, including on standards.

A role for electrification and hydrogen

Looking ahead, alternative technologies, particularly electrification, are expected to play a pivotal role in accelerating the transition to sustainable aviation. However, this shift hinges on a significant breakthrough in battery technology, particularly in terms of energy density. Hydrogen aviation could be another long-term solution, particularly for long-haul flights, but its potential is yet to be proven.

Aviation: Policy opportunities for accelerating the transition

Achieving a >1000x scale-up of SAF by 2030 will necessitate a long-term internationally coordinated policy framework to support both production and demand. Such a framework would be most likely to succeed if initiated by a small group of governments which represent major international airport hubs – a group big enough to drive change, but small enough to reach agreement on the key measures required to accelerate the rational and coordinated decarbonization of the industry.

The focus of any joint action should be to create a stable international policy framework to drive the global demand and uptake of SAF and ensure a level playing field among major airport hubs, including by addressing fiscal imbalances for aviation fuel. This might involve a voluntary international alliance among countries which commits to introduce ratcheting SAF blending mandates, subsidized through air passenger duties. This could be supported by a single international book and claim trading scheme, administered among governments, to ensure SAF could be used most efficiently at the point of least cost production, as well as measures to support the rapid scale of SAF in geographies where the potential for low-cost production is greatest.

Another potential growth area is investments in the SAF value chain made by demand-side companies seeking to reduce their travel and freight footprint, which would need to be recognized through flexible approaches for scope 3 emissions.

SECTOR SUMMARIES: HYDROGEN

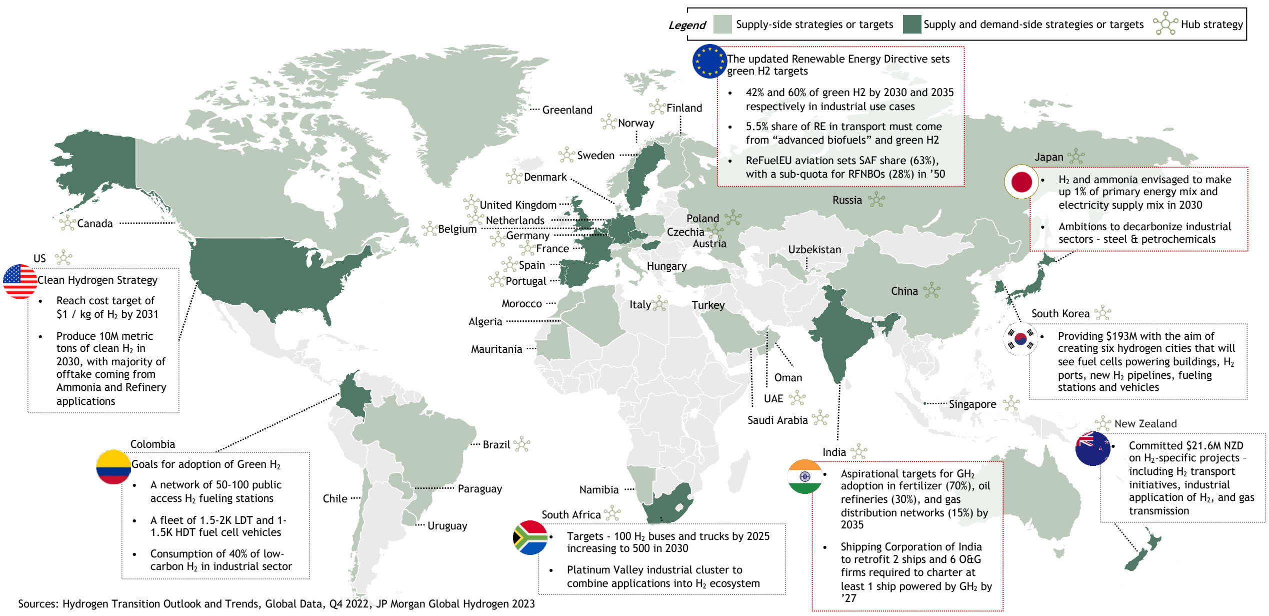
Hydrogen plays a crucial role in the decarbonization of several industries including steel, shipping and freight. That said, sustained government intervention will be needed to develop the market for green hydrogen - more than 50% of business leaders surveyed believe that the commercial viability of green hydrogen and supporting infrastructure are significant barriers to successfully transitioning the sector.

The creation of a low carbon hydrogen economy is nevertheless underway, propelled by policy, and accelerating following Russia›s invasion of Ukraine in 2022. Across the globe, over 40 countries have announced hydrogen strategies, aiming to create end-market demand, as well as assisting producers in accelerating deployment of key technologies like electrolyzers, and supporting the expansion of physical transport, storage, and distribution infrastructure.

Supporting the demand side transition to hydrogen

Global demand for green hydrogen is being catalyzed through demand side policy across the shipping, aviation, and industry sectors. In the absence of policy to create demand, corporate willingness across end-markets to investment in low-carbon hydrogen products is limited due to the cost premium of clean hydrogen - depending on regional renewable electricity prices, green hydrogen can still cost nearly four times as much as fossil-dependent "grey" hydrogen produced from natural gas.

Fig. 17. 40+ countries across the globe have released green hydrogen strategies

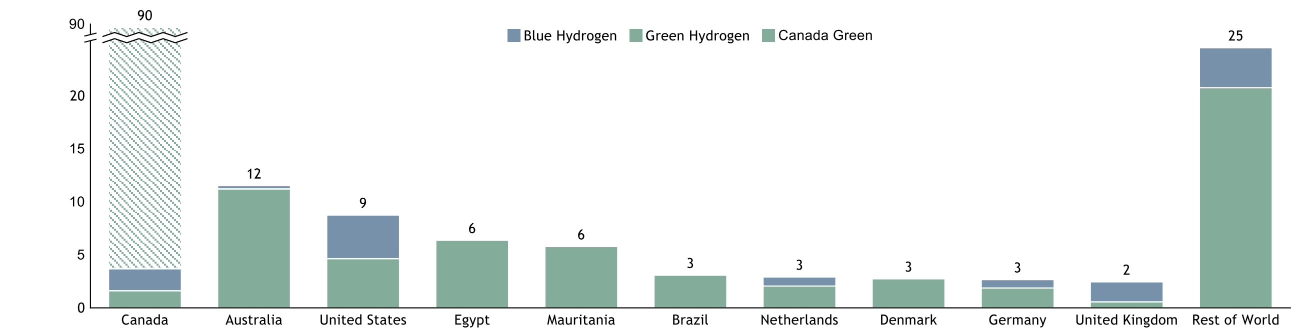


Sources: Hydrogen Transition Outlook and Trends, Global Data, Q4 2022, JP Morgan Global Hydrogen 2023

Scaling the supply of low carbon hydrogen

There is no shortage of announced low-carbon hydrogen projects, with over 1,000 around the world creating a project pipeline tracking to over 160M metric tons by 2030. While almost all are in early stage and may not materialize, operationalizing a share of these projects will fuel an anticipated ~9-18% learning rate that will propel hydrogen down the cost curve over the next 5-10 years. As electrolyzer costs fall, green hydrogen production costs will be increasingly determined by electricity costs.In some regions this could be set by the marginal price of curtailed renewables - i.e. renewable generation that that cannot be accepted by the grid due to transmission congestion - as the business case for variable renewables is increasingly built around sector coupling to avoid curtailment and maximise returns. Clean hydrogen projects in the pipeline suggest there will be regional differences in the contributions of green and "blue" hydrogen (traditional hydrogen production with CCUS – or nuclear powered hydrogen production) come 2030. But the scale-up of electrolyzer capacity faces constraints from potential restrictions on PFAS (a polymer used in membranes), coupled with short supplies of iridium (a catalyst for hydrogen production), as well as competition for renewable electricity supply in some places.

Fig. 18. Production capacity of active and announced low-carbon hydrogen projects (Million tonnes p.a., 2030)



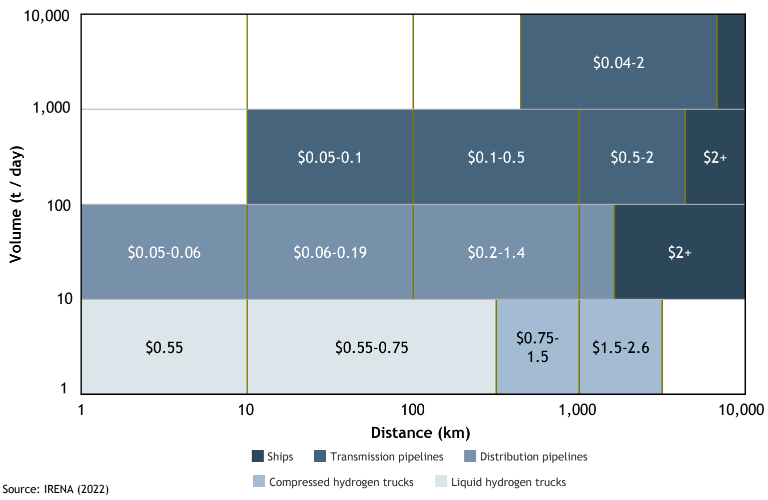
	Canada	Australia	United States	Egypt	Mauritania	Brazil	Netherlands	Denmark	Germany	United Kingdom	Rest of World
Project Count	34	137	96	20	5	16	64	37	125	73	598
Share of capacity in early-stage	98.5%	98.2%	93.8%	99.8%	100.0%	99.7%	99.9%	98.8%	99.2%	98.5%	91.3%

Note: Capacity and project count figures assume any non-stalled project projected to start production by 2030 will be in production by 2030; Early-stage projects are those in the approval, feasibility, or FEED (front-end engineering and design) stage, late-stage projects are those in the approval, commissioning, or construction stage.
Source: GlobalData Low-Carbon Hydrogen Database

Enabling infrastructure

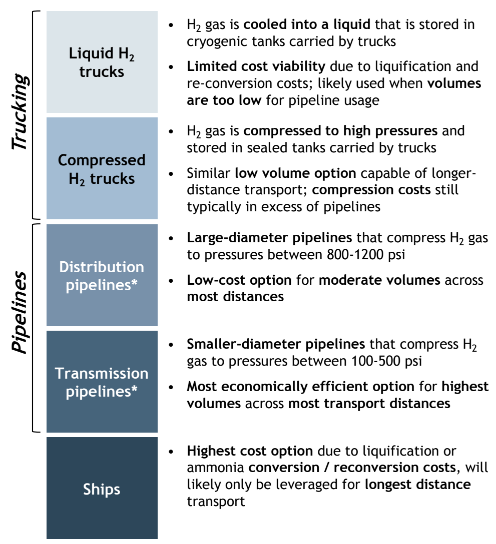
In the short term, hydrogen hubs are enabling the co-location of production, demand, and favorable market conditions. But longer-term, business leaders lack alignment on anticipated transportation methods for hydrogen, with significant splits across pipelines, shipping, or other methods. Storage costs will also limit cost competitiveness of non-co-located hydrogen production due to geographic and volume constraints for the cheapest storage options.

Fig. 19. Pipelines are the most cost-effective long-range transport option in the near-term



Source: IRENA (2022)

Fig. 20. Description of transport methods



Hydrogen: Policy opportunities for accelerating the transition

International collaboration between both governments and businesses is pivotal for the rapid expansion of the green hydrogen industry. Top of the list of priorities is harmonizing standards for green hydrogen, including the assessment of associated emissions, in order to lock in demand and make climate benefits clear. Agreeing common approaches to safety and infrastructure development are also important.

Greater coordination on demand side policy across regions, including prioritizing different use cases and hydrogen derivatives, would help ensure a more attractive investment environment for hydrogen producers, given the diversified nature of hydrogen use cases. International cooperation will also be essential for aligning approaches to international trade, as well as pooling resources and risk for demonstration demand-side projects in high-priority sectors, like shipping or steel.

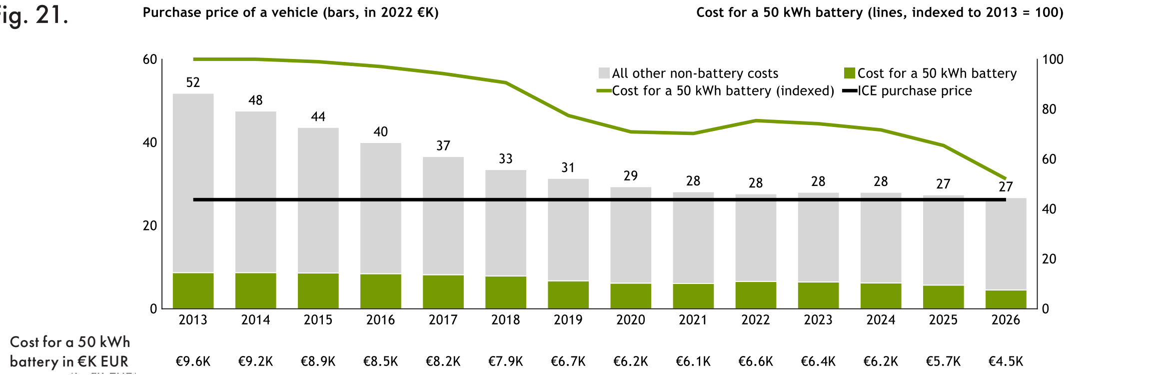
SECTOR SUMMARIES: ROAD TRANSPORT

Road transport represents 16% of global CO2 emissions. Clean energy transitions are taking off across vehicle types - global passenger EV sales grew 4 times from 2020-2023 and passenger EV sales passed 10% penetration of the global market in 2021. This trend will continue to accelerate through the next decade, with the pace determined by the extent to which proven policy approaches can be replicated across economies, including for charging infrastructure.

Passenger vehicle – beyond the tipping point in developed markets

In the passenger vehicle market, combustion engine sales have already peaked. Yet business leaders think commercial viability, alignment on standards, and willingness to adopt are still holding back the transition. Continued reductions in battery cost should drive purchase price parity with internal combustion engine (ICE) vehicles in the next couple of years. But it's the lag in charging infrastructure investment that remains the biggest barrier, and prevents faster consumer uptake. Governments need more focused strategies to overcome this, including through public-private partnerships.

Fig. 21.

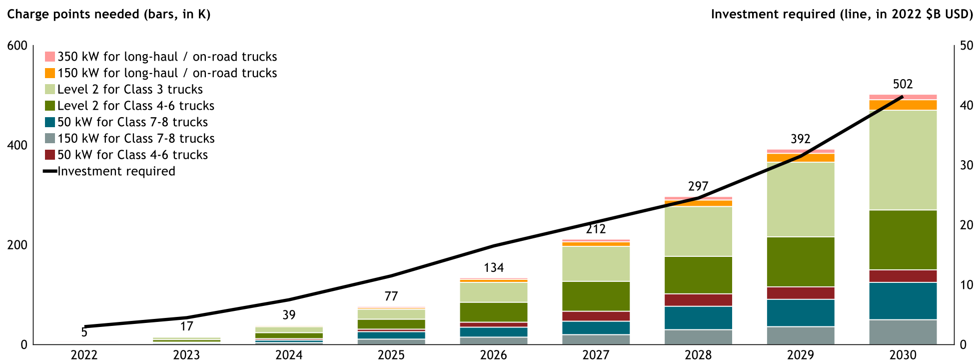


Note: Cell module costs based upon industry reports of projected prices for cobalt, lithium, nickel, and other materials for cell module; Cell module scaled to assumed battery size to determine battery costs; All other non-battery costs include electric motor and inverter, materials costs, and production & development costs based upon costs for the Volkswagen ID.3 Pro in Germany; ICE price based on VW Golf 2.0 in Germany.
Source: P3/Bain battery cost model

Removing roadblocks to net-zero freight

Many electric freight vehicle types are on a path to reaching total cost of operation (TCO) parity with ICE trucks within the next decade. Business leaders nonetheless view commercial viability as the top barrier to transition Government intervention to drive adoption is proving critical for driving the early-stage adoption as technologies mature. The slow pace of charging infrastructure build out is also a major concern – several major fleet operators are taking matters into their own hands for both short- and long-range vehicles, however business and government will need to work more closely together to boost the transition in longer range vehicles.

Fig. 22.

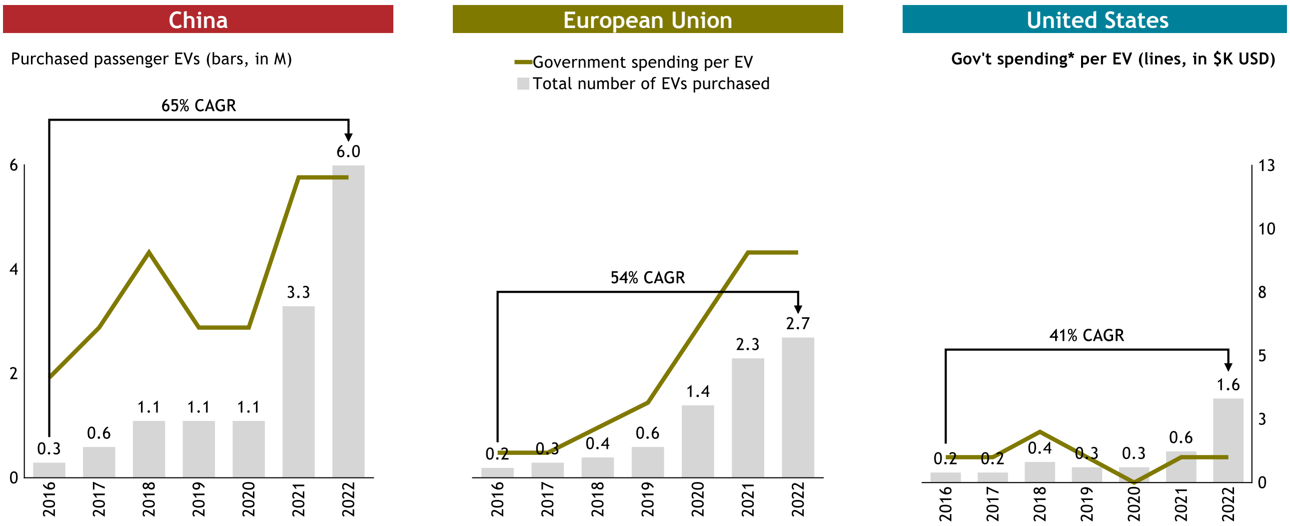


Source: Atlas Public Policy, US Department of Transportation; Corporate interviews

Sustaining the EV transition

Business leaders see infrastructure development and government finance as key factors attracting investment in EVs in early-stage markets. Significant government investment certainly proved critical for kickstarting the EV revolution in China, which is estimated to have spent more than $15B from 2016-2022 to drive a 20x increase in annual EV purchases. Many developing and emerging economies are also putting in place measures to support EV adoption, but international support could accelerate progress and reduce financing costs. Global vehicle manufacturers could invest in local production and distribution to ease purchase prices, provided that challenges related to country risk and cost of capital are overcome. To that end, development banks could support investments in power supply and charging infrastructure, including through blended finance (public-private), as well as supporting public procurement programs, further de-risking and lowering the costs of future EV investments.

Fig. 23.



Note: (*) Government spending includes spending on vehicle subsidies, charging infrastructure, and battery supply chains.
Source: IEA, Electric Vehicles Initiative, Energy Research Institute, Reuters.

Road transport: Policy opportunities for accelerating the transition

An inevitable transition is currently underway in passenger vehicles. The pace will be set by national policymaking and accelerated through international alignment. Central to this is a stronger demand-side policy, including country-level commitments to phase out internal combustion engine sales. Commitments to the rollout of infrastructure are important, such as mandated build-out of charging infrastructure in new building, parking, and road construction projects, with cross-border consistency where possible. International standardization of charging connections and means for open access to on-the-go infrastructure will also be important.

The transition of heavy-duty vehicles is at an earlier stage, but consistent, and ideally internationally coordinated policy framework can help accelerate adoption, again with a focus on common standards for vehicles and charging infrastructure and coordination of demand-side policies to encourage market growth.

Beyond developed markets, the next wave of the EV revolution is less certain. International assistance, including policy and financial support, is important. However, transitions in emerging and developing countries will progress more swiftly if countries have a stake in growing EV value chains, whether that in vehicle or battery manufacturing.

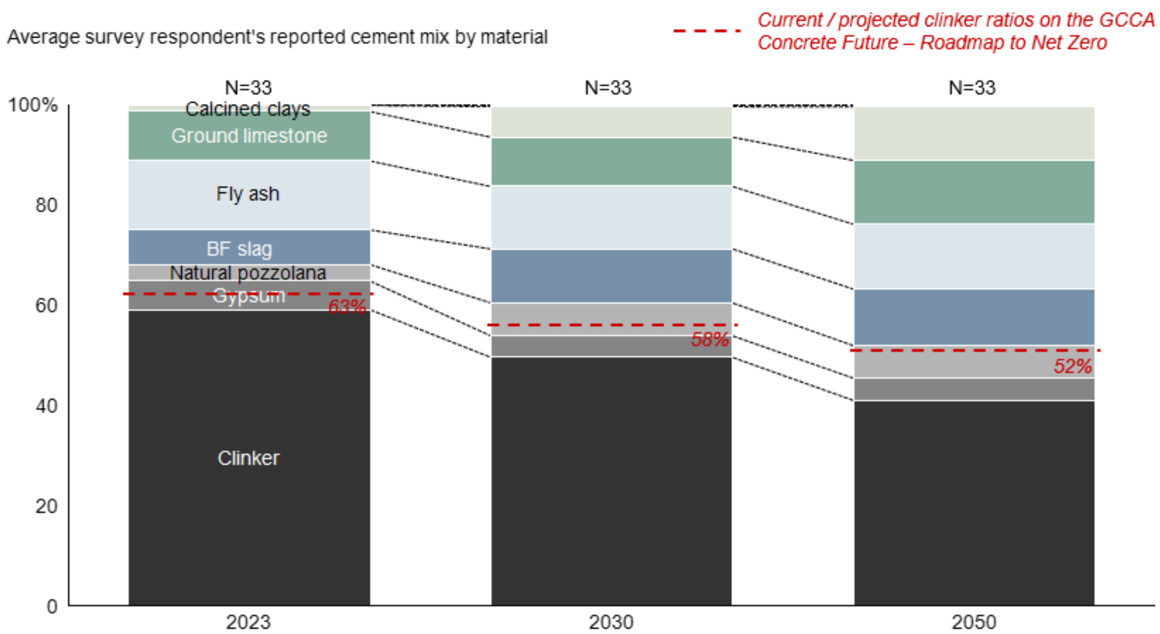
SECTOR SUMMARIES: CEMENT & CONCRETE

Concrete is the second most consumed material on Earth after water, with an outsized role to play in our collective efforts to reach net zero emissions globally by 2050, accounting for around 7% of total CO2 emissions. Carbon is emitted throughout the cement and concrete lifecycle, but clinker production is responsible for 88% of emissions, the majority of which are emitted through the calcination of raw materials and the combustion of fossil fuels.. The road to full decarbonization is extremely challenging. Technological challenges abound, and while several leading companies have set Science-Based Targets, less than 20% of the cement market is reporting climate-related information to CDP, with most companies neither setting nor progressing towards meeting IEA NZ-aligned targets.

Substituting clinker in concrete and cement

Reducing the proportion of clinker used in cement is one avenue to reduce overall emissions intensity. Global average clinker ratios are estimated to have dropped 8% since 2005. Producers expect the average clinker ratio to drop from ~60% to ~50%, and even 40% for some respondents, replaced by a combination of several clinker substitutes. But business leaders are concerned with the viability of clinker alternatives as the supply of common clinker substitutes like fly ash (mostly from coal-fired power generation) and ground granulated blast furnace slag is dwindling in certain markets as the broader energy transition accelerates. The remaining alternatives, namely calcined clays, ground limestone, and alternative pozzolans, face barriers to adoption, particularly around cost, but also a reticence among construction companies to adopt lower clinker ratio mixes. As governments represent >20% of global land ownership and >30% of concrete and cement procurement, government procurement power has an outsized influence in encouraging clinker substitution. This procurement not only guarantees demand for producers to expand capacity, but also demonstrates proof points for private actors to shift to lower clinker mixes too.

Fig. 24. We would like to understand how cement producers are thinking about potential clinker substitutes. What is the **average mix of your cement** today? In 2030? In 2050?



The GCCA industry decarbonization pathway expects clinker binder factor to reduce to 58% and 52% by 2030 and 2050 respectively. The survey respondents see that clinker ratio of even 40% is attainable by 2050.

Replacing fossil fuels in kiln heating

Alternatives to coal used in kiln heating, the source of ~35% of emissions from the concrete & cement sector, have seen adoption double over the last decade. The GCCA net zero roadmap foresees alternative fuel usage to increase to 43% by 2050. To ensure that fossil fuel usage in kiln heating is reduced, policymakers should consider business leaders' concerns regarding access to the supply of fossil fuel alternatives. As the supply of biomass and waste substitutes are constrained and geographically dispersed, and with biomass having its own sustainability challenges, governments should ensure robust waste management and anti-dumping laws to faciliatete the use of waste substitutes. Moreover, a long-term pathway to decarbonize kiln heating will require increased support for investments in electrification and green hydrogen.

Fig. 23. Average cost in 2020 ($/ton of cement)

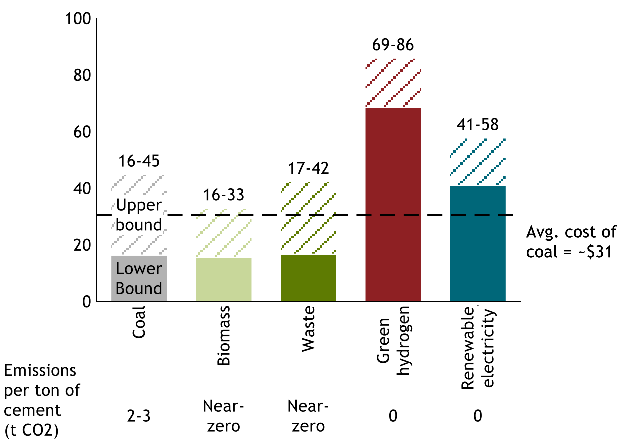
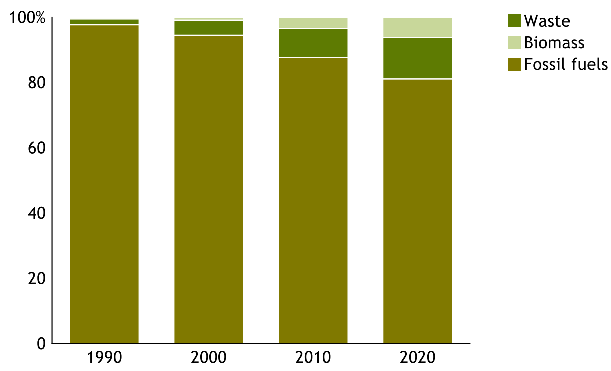


Fig. 24. Global cement thermal energy mix over time (%)

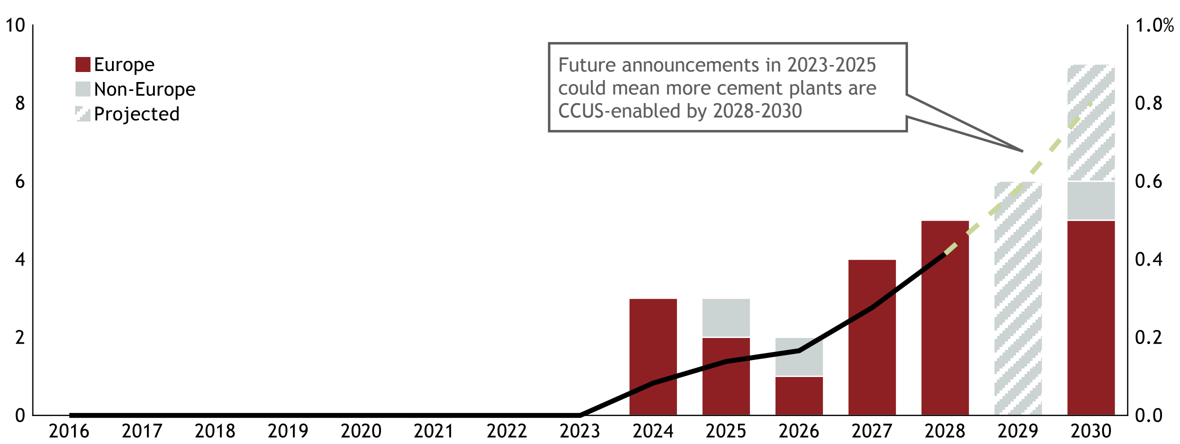


Note: Cost of carbon capture assumes CO2 usage in cement is .59t CO2 / metric ton of cement per IEA 2021 report; A 0.8 metric tons of clinker / 1 metric ton cement ratio was assumed; the average of high and low estimated bounds was used as projection; CCUS cost per metric ton was removed from cost estimates at a flat rate across all FF alternatives based on RMI cost estimates for CCUS; other alternatives have ranged 2020 price estimates, to reflect regional differences in pricing.
Source: RMI; World Cement; IEA 2021 report; GNR; Kahawalge, A. "Opportunities and challenges of using SRF as an alternative fuel in the cement industry"

Adopting carbon capture, utilization, and storage

Significant investment in infrastructure will be needed to enable industry-wide carbon capture, transport, utilisation and storage. Although technology cost is currently considered a barrier, the GCCA roadmap expects CCUS to provide 36% (1370Mt CO2) of the emission reductions required for a net zero concrete & cement industry by 2050. In the near term, a growing number of announcements from producers suggest that there will be more than 20 commercial-scale CCUS plants online by 2030, but this figure represents less than 1% of plants.

Fig. 25. # of cement CCUS projects coming online (bars) % of cement plants CCUS-enabled (line)



Note: Data includes all operational, under construction and planned CO2 capture facilities with an announced capacity of more than 100 000 t per year (or 1000 t per year for direct air capture facilities). 7 CCUS projects do not have an operational year -- those plants have an announced average capacity of 1.247 MT CO2/yr; 4 of the plants without operational years were outside Europe; 2 CCUS projects do not have announced capacities; lower bound estimates used for announced capacity of plants | Source: IEA CCUS Projects Database; GECD; GCCA; Leadit; Corporate interviews

Cement: policy opportunities for accelerating the transition

The cement industry has particular characteristics that make cross-border government intervention very important for accelerating the transition: notably its local nature (cement is heavy to transport and so mostly consumed locally), and its relative lack of currently viable net-zero technology options.

International standards have an important role to play, including for the use of clinker alternatives as well as for raising minimum standards of production among the major economies. Facilitating capacity building and technology transfer to support the use of lower carbon concrete and cement in emerging economies will be essential, given important demand growth for cement in those regions. Policies to support the development and financing of CCUS will be essential for achieving a net-zero cement industry, both generally (such as for CO2 transport and storage infrastructure) as well as specifically to help drive down costs of CO2 capture during cement production.

SECTOR SUMMARIES: SHIPPING

Governments have given shipping industry leaders a roadmap for the industry to decarbonize by 2050, thanks to the 2023 International Maritime Organization (IMO) GHG Strategy. But shipping business leaders point to multiple barriers holding back their investment in a lower carbon industry – from technical concerns particularly around ammonia, the lack of infrastructure investment, to continuing questions over commercial viability. Only a small share of shipping companies reports to the CDP, though 60% of those who are reporting are meeting IEA 2030 milestones.

Driving adoption of near-term operational efficiencies

Evidence from this Stocktake shows that less than 40% of ship operators anticipate retiring ships in favor of low-emission vessels prior to 20 years of service. This makes near term action to fully implement operational efficiencies critical. Ship operators have demonstrated significant adoption of near-term operational efficiency practices – but there is more work to do and international standards can play a key role. The IMO's MARPOL 2020 regulation on sulphur emissions has shown how effective global regulation can be for shipping – and has driven rapid adoption of scrubbers, for example.

Fig. 26.

Category	Example efficiency practices	Efficiency potential	*Current adoption by ship type* Bulk	Tanker	Container	Passenger
Voyage optimization	• **Weather routing:** Planning routes around expected weather to maximize efficiency • **Hull and propeller fouling management:** Maintenance practices to avoid accumulation of living organisms and debris	10%	◕	◕	●	●
Fleet strategies	• **Fleet portfolio optimization:** Optimizing mix of different ship sizes to fleet needs • **Scheduling and speed optimization:** Optimizing delivery times and speeds to allow for energy efficient "slow steaming"	15%	◑	◑	◕	●
Hull & propeller efficiency	• **Propeller design:** Optimizing propeller configuration for ship and route needs • **Air lubrication:** Reducing resistance between hull and water using air bubbles	8%	◑	◑	◕	●
Engines & systems	• **Engine technology:** Powering intake and exhaust valves hydraulically or mechanically • **Waste heat recovery:** Recapturing heat from ship operations as a form of energy	5%	◑	◑	◕	●
Alternative power systems	• **Wind-assisted propulsion:** Capturing wind surrounding ship during travel as source of propulsion	8%	◔	◔	○	◔

Note: Expected efficiency uptick for fuel consumption is correlated with carbon emissions; CII = Carbon Intensity Indicator.
Source: Maersk McKinney Moller Center Maritime Decarbonization Strategy 2021 and 2022

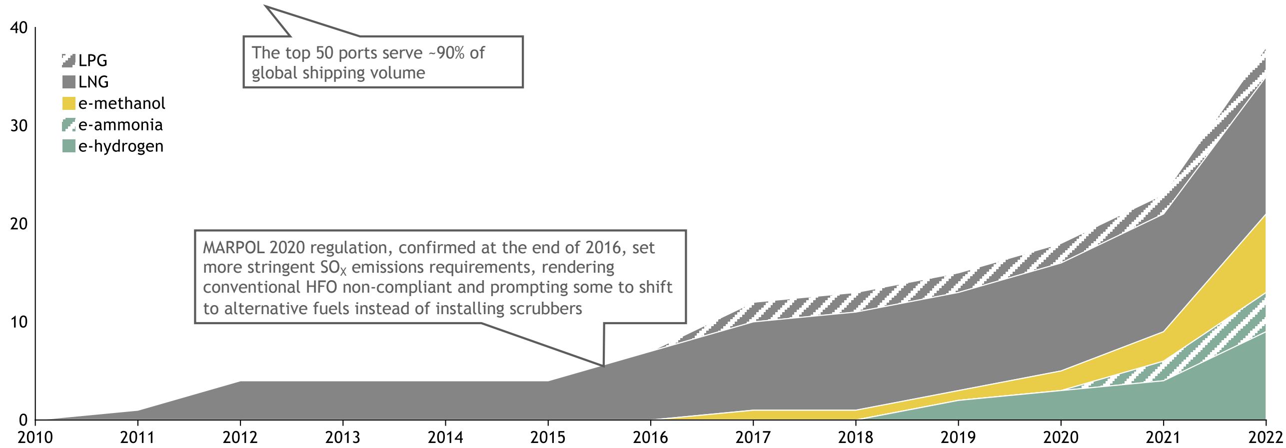
Near-term alternative fuel trialing

The shipping industry is exploring multiple alternative fuels. Over the next five years many in the industry will be focused on rivaling solutions such as ammonia, methanol, hydrogen, and batteries, with the lack of alignment over technology pathways a significant barrier to investment. Only the most forward-leading companies are committing significant capital to bring zero carbon vessels to market, with most companies surveyed emphasizing the importance of spreading risk through collaboration, such as «green corridors,», where zero-emissions vessels are incentivized.

Stepping up the pace towards zero emission fuels

Ship operators view ammonia as the long-term frontrunner to decarbonize the sector, but the challenges are significant. More than half (55%) of business leaders in the shipping sector surveyed cite technical feasibility as a top barrier to adopting alternative fuels. The global order books for zero-emissions vessels grew 6x from 2019 to 2022, driven by uptake of methanol, ammonia, and hydrogen ready vessels. Bunkering and fuel supply is also beginning to take off. While in 2016 there were almost no shipping ports planning any zero-emissions fuel bunkering, by the end of 2022 shipping ports representing ~16% of global shipping volume had announced plans to build out zero-emissions fuel bunkering. Green methanol supply has also been growing rapidly with total global production capacity (of bio methanol and e-methanol) growing 450% from 2020 to 2023, albeit from a low base.

Fig. 27. Cumulative number of Top 50 port announcing investments in alternative fuel bunkering by type



Note: Top 50 ports determined by annual container volume by TEUs as of 2021; Assume 1 TEU = ~26 metric tons.
Source: World Shipping Council, Fourth IMO GHG Study 2020, 2023 IMO GHG Strategy

Shipping: Policy options for accelerating the transition

Global coordination will be essential for enabling systems alignment in terms of fuels, technologies choices and the infrastructure investment required over the coming decades, as well as ensuring a level playing field among ship operators. The IMO has set an ambitious GHG emission reduction strategy, which is intended to be followed in 2025 by the adoption of near-term measures that would enable these goals. Achieving this kind of international agreement at the level of the IMO would be game-changing for a fledgling green shipping industry. But it will not be easy, and it may be more practical to also drive progress in smaller constellations.

Strong regulation across the 15 ports representing ~80% of global shipping volume would be almost as significant in driving system-wide transition to zero-emissions fuels. Such an alliance of governments could pioneer an international framework setting international carbon emissions standards and investing in bunkering infrastructure for alternative fuels. Additionally, the coalition can amplify the uptake of zero-emission vessels by endorsing industrial-scale demonstration projects and offering financial incentives for vessel procurement – such as differentiated harboring fees based on type of vessel to differentiated pricing of marine fuel based on carbon content.

SECTOR SUMMARIES: AGRICULTURE

The food system accounts for 25-35% of global emissions – and is set to rise driven by a growing global population and increasing wealth leading to more emissions-intensive diets. In the agriculture segment of the food systems, emissions primarily come from a mix of carbon dioxide, methane, and nitrous oxide. 50% of anthropogenic methane emissions come from the food system, primarily from livestock. At COP26, the Global Methane Pledge was announced to cut methane levels by 30% by 2030, including agriculture.

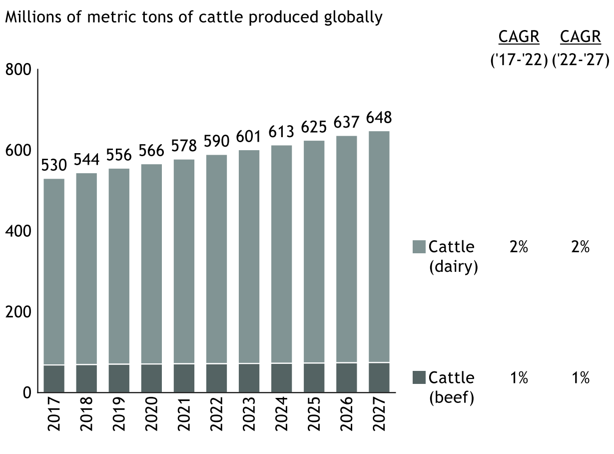
Minimize land use change

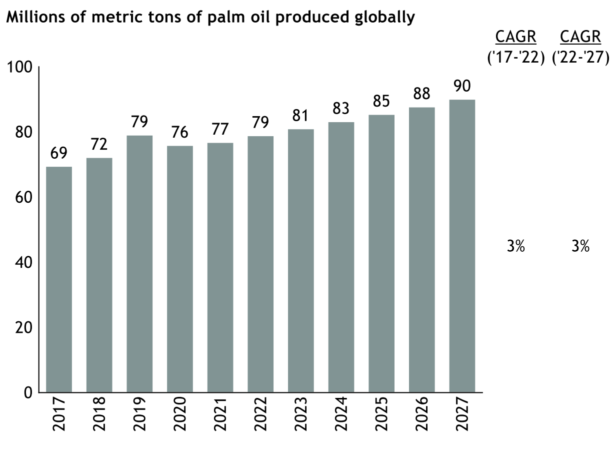
A significant share of CO2 emissions from the food system come from land use change, specifically tropical deforestation and the draining of carbon-rich peatlands. Voluntary and regulatory commitments to prevent deforestation are increasing.

- At COP26, the Declaration on Forests and Land Use announced targets of zero net-deforestation by 2030, and the EU has proposed regulation preventing the import of goods linked to deforestation (e.g., cocoa, coffee, palm oil).
- Companies are making zero-deforestation commitments in their supply chains, and Science-Based targets are now meant to incorporate emissions reductions goals for land use change emissions with the release of the Forest, Land and Agriculture (FLAG) guidance for target setting.
- The EU has introduced a deforestation-free supply chain for 7 key commodities, requiring proof that products don›t originate from recently deforested areas.

But despite these initiatives, the underlying incentives driving deforestation remain strong – principally rising demand and prices for commodities linked to deforestation, such as beef and palm oil. Since the peak in 2016-2017, deforestation rates are largely flat, and it's possible that voluntary and regulatory measures which focus on driving greater scrutiny on supply chains may simply result in resource shuffling.

Fig. 28.



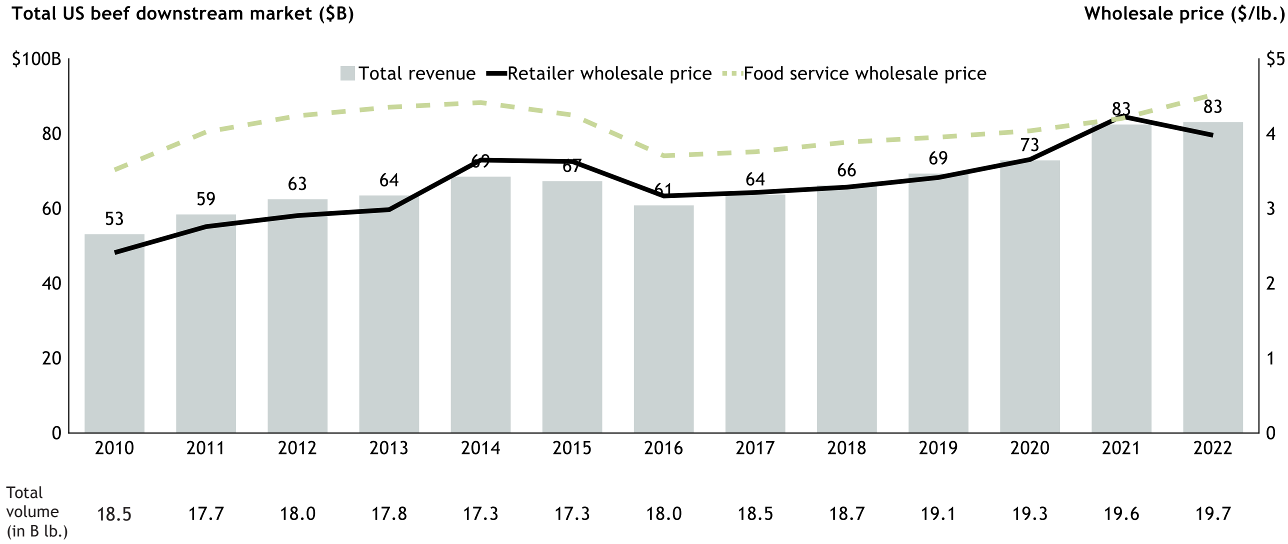


Source: OECD-FAO Agricultural Outlook, FAO Stat, USDA, Reuters

Mitigating on-farm livestock emissions

Beef and dairy consumption continue to grow steadily, primarily driven by increased growth in developing markets. Increasing prices and a lack of price elasticity is creating strong incentives for further growth in supply. Solutions exist for reducing emissions – including feed additives and anaerobic digesters, but cost barriers are holding back widespread adoption.

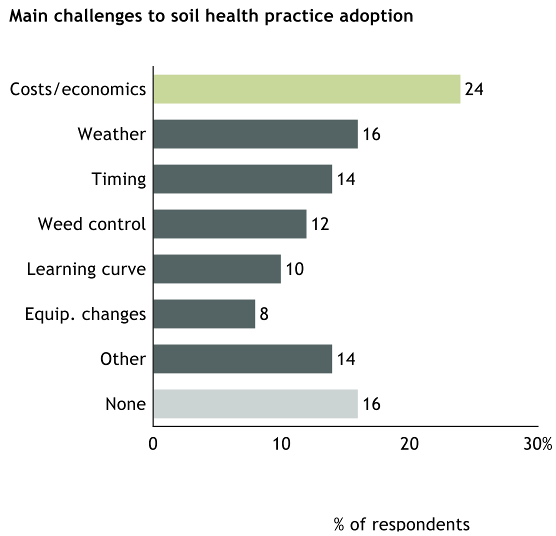
Fig. 29.

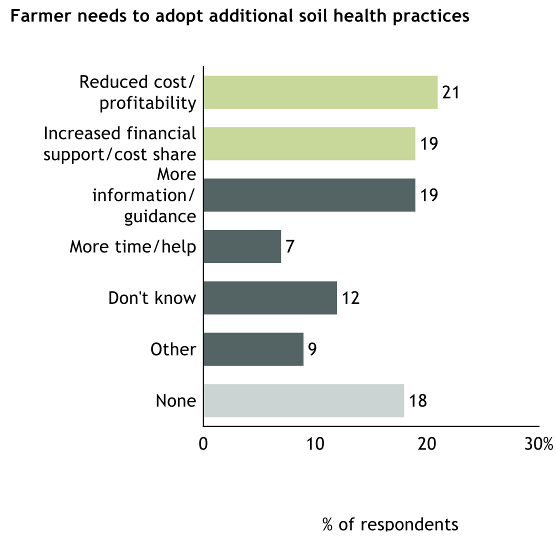


Note: Downstream market size is based on wholesale price (the price that retailers and food service providers pay to procure beef)
Source: Meat Demand Monitor, USDA Economic Research Services, Euromonitor, GlobalData, Technomic

Mitigating on-farm crop emissions

There are signs that adoption of regenerative agriculture is taking off in some markets – including the US. This will help reduce emissions and increase farm resilience. But scaling these practices requires significant upfront costs and risks yield drag in the short-term as farmers implement new techniques, while long term gains can be unpredictable creating risks for farmers. Businesses further up the supply chain are concerned that farmers are not getting the access to funding and technical support they need to scale regenerative agricultural practices.





Note: 2021 survey of 100 Iowa farmers.
Source: The Environmental Defense Fund: Banking on Soil Health, Transforming food systems with farmers: A pathway for the EU (WEF, 2022); New York Times: Companies' climate promises face a wild card: Farmers

Agriculture: Policy options for accelerating the transition

The solutions for agriculture are complex. Tackling deforestation requires addressing the underlying economic dynamics; supply chain approaches are valuable but can only achieve so much, particularly in a world where demand for the underlying commodities is rising, and value chains are often long and opaque. Alongside this, better international coordination could help ensure more sustainable demand for the underlying commodities driving land use change, provide new mechanisms for improving financial incentives for landowners, while increasing shared learning on successful jurisdictional approaches.

In both livestock and arable farming, a paradigm shift is also needed to bring new technologies to market that both enable productivity as well as decarbonization, as well as measures which will accelerate access to training and technical assistance on regenerative agriculture.