BREAKTHROUGH AGENDA

THE BREAKTHROUGH AGENDA REPORT 2023

Accelerating Sector Transitions Through Stronger International Collaboration

IEA

IRENA
International Renewable Energy Agency

UN Climate Change High-Level Champions
in collaboration with:

Marrakech Partnership | Global Climate Action

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The UN Climate Change High-Level Champions mobilise non-state actors for stronger and more ambitious climate action. Mandated by Parties of the Paris Agreement, and working with the Marrakech Partnership, the two serving HLCs Dr. Mahmoud Mohieldin and Ms. Razan Al Mubarak build on the legacy of their predecessors to engage with non-state actors and activate the 'ambition loop' with national governments, connecting policy with the many voluntary and collaborative actions taken by cities, regions, businesses and investors, and nations. Their work is fundamentally designed to encourage a collaborative shift across all of society towards a decarbonised economy so that we can all thrive in a healthy, resilient and zero carbon world. The Climate Champions Team (CCT) is the delivery arm of the UN Climate Change High-Level Champions.

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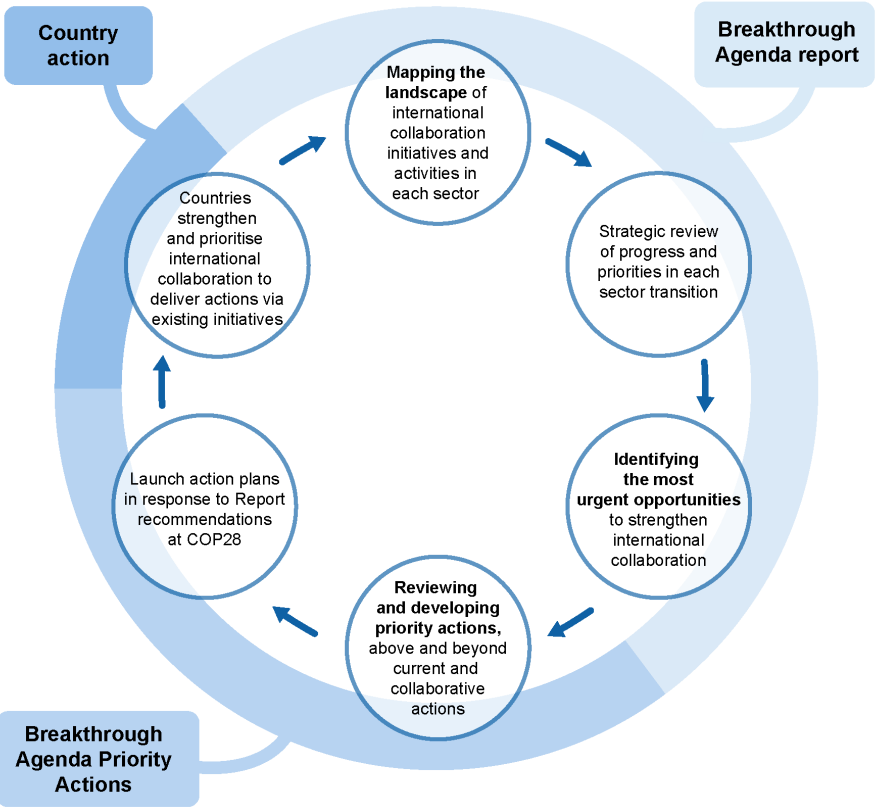
ABOUT THIS REPORT

The Breakthrough Agenda was launched by 45 world leaders at COP 26 and is a commitment to work together this decade to accelerate innovation and deployment of clean technologies, making them accessible and affordable for all this decade. To kick-start this Agenda, countries endorsed Breakthrough goals to make clean technologies and sustainable practices more affordable, accessible and attractive than their alternatives by 2030 in the power, road transport, steel, hydrogen and agriculture sectors. This report also covers the buildings and cement sectors, where new breakthroughs are being considered.

The Breakthrough Agenda establishes an annual cycle to track developments towards these goals, identify where further co-ordinated international action is urgently needed to accelerate progress and then galvanise public and private international action behind these specific priorities in order to make these transitions quicker, cheaper and easier for all.



To initiate this cycle, world leaders tasked the IEA, IRENA and the UN Climate Change High Level Champions to develop an annual Breakthrough Agenda report to provide an independent evidence base and expert recommendations for where stronger international collaboration is needed.

This document, the 2023 Breakthrough Agenda Report, is the second of these annual reports. For sectors addressed in 2022, it provides an assessment of progress against the recommendations made last year, updating recommendations for what more needs to be done. For sectors added in 2023, namely buildings and cement, it provides an assessment of each Breakthrough goal, a pathway of co-ordinated international actions through to 2030, and a set of specific recommendations on the most urgent and high-impact opportunities to strengthen international collaboration.

Breakthrough Agenda Signatories:

As of August 2023 the Breakthrough Agenda signatories are: Australia, Austria, Azerbaijan, Belgium, Cabo Verde, Cambodia, Canada, Chile, China, Denmark, Egypt, European Union, Finland, France, Germany, Guinea-Bissau, the Holy See, India, Ireland, Israel, Italy, Japan, Kenya, Latvia, Lithuania, Luxembourg, Malta, Mauritania, Morocco, Namibia, Netherlands, New Zealand, Nigeria, North Macedonia, Norway, Panama, Portugal, Republic of Korea, Senegal, Serbia, Slovakia, Slovenia, Spain, Sweden, Türkiye, United Arab Emirates, United Kingdom, United States.

FOREWORD

Over the past year, we have seen an acceleration in the global low-carbon transition, with progress often happening faster than most realise. This includes record deployment of solar PV, electric cars and heat pumps, which are all important solutions as countries transition to net zero emissions.

However, it is also clear that the transition is still not going fast enough – and is occurring at very different speeds across regions and sectors. For example, the record deployment of renewables and the incredibly rapid growth in sales of electric vehicles that took place in 2022 were both heavily concentrated in China, Europe and the United States. Stronger international collaboration is urgently needed to accelerate the pace of a just transition, ensuring that clean technologies and sustainable solutions are accessible to all.

This *Breakthrough Agenda Report 2023,* the second in an annual series, assesses progress on international collaboration in seven major emitting sectors. This includes the five sectors covered in last year's report – power, hydrogen, road transport, steel and agriculture – as well as buildings and cement. Should countries agree to work together towards breakthrough goals in these new sectors, as is now being considered, the Breakthrough Agenda will cover 60% of global greenhouse gas emissions.

This report is a joint product of the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA) and the UN Climate Change High-Level Champions. Each organisation has brought its own expertise to assess progress in international collaboration, and to deliver clear recommendations for the actions that governments and non-state actors need to take together. It also draws on global expertise generously shared by governments, businesses and civil society organisations active in each of the sectors covered.

Overall, the report finds only modest progress in strengthening international collaboration in these sectors. There have been some examples of good progress, which can provide a blueprint for other sectors and initiatives. These include collaboration on standards and definitions for near-zero emission green steel and low-carbon hydrogen, the trade of used internal combustion engine vehicles, and rising commitments to invest in research and development in several sectors.

There remains significant scope for stronger international collaboration in all sectors. This requires greater commitment and participation from all involved. The priorities include governments and businesses sending stronger, collective demand signals for sustainable products (such as low-carbon hydrogen, steel and cement); a continued improvement in the coordination, scale, and effectiveness of financial and technical assistance provided to developing countries; stronger, more sustained public-private collaboration on research and innovation across several sectors; and targeted collaboration on trade.

We hope that the recommendations in this report provide a practical, detailed roadmap for stronger international collaboration. We look forward to continuing to support governments, businesses and civil society organisations in their efforts to implement the recommendations of this report, as we work together to make the transition to clean technologies and sustainable solutions faster, easier and more affordable for all. We need to incorporate the full range of environmental, social, economic and governance dimensions and to address transitional challenges, especially in developing countries. The acceleration in the global low-carbon transition must be connected with inclusive development pathways through ensuring linkages with and contribution to the 2030 Agenda for Sustainable Development.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

STRENGTHENING INTERNATIONAL COLLABORATION TO ACCELERATE TRANSITIONS

The transition to clean energy and sustainable solutions is accelerating across many sectors, with unprecedented expansion in clean technologies such as solar PV and electric cars. Renewable electricity is now more affordable than fossil fuel-based electricity in a growing number of countries and contributes to more than 50% of electricity generation in around 30% of countries. Sales of electric passenger cars are growing exponentially and – if this rate continues – could by 2030 be comfortably in line with what is required under a scenario compatible with reaching net zero CO_2 emissions by 2050.

Yet, global emissions are still increasing, and the Nationally Determined Contributions that countries have put forward in UN climate change negotiations are not consistent with curbing temperature rise in line with international climate goals. The past year has also been notable for record temperatures, and extreme weather events are continuing to increase in frequency and intensity in many parts of the world.

Action this decade will be crucial to head off the worst effects of climate change. Some of the solutions required to decarbonise certain sectors are not yet deployed at scale, and can take several years to develop, meaning first steps towards deployment are needed now. What's more, investment in clean energy technologies and low-emission products and materials tends to be concentrated in advanced economies, and not in the countries undergoing the most rapid development and economic growth.

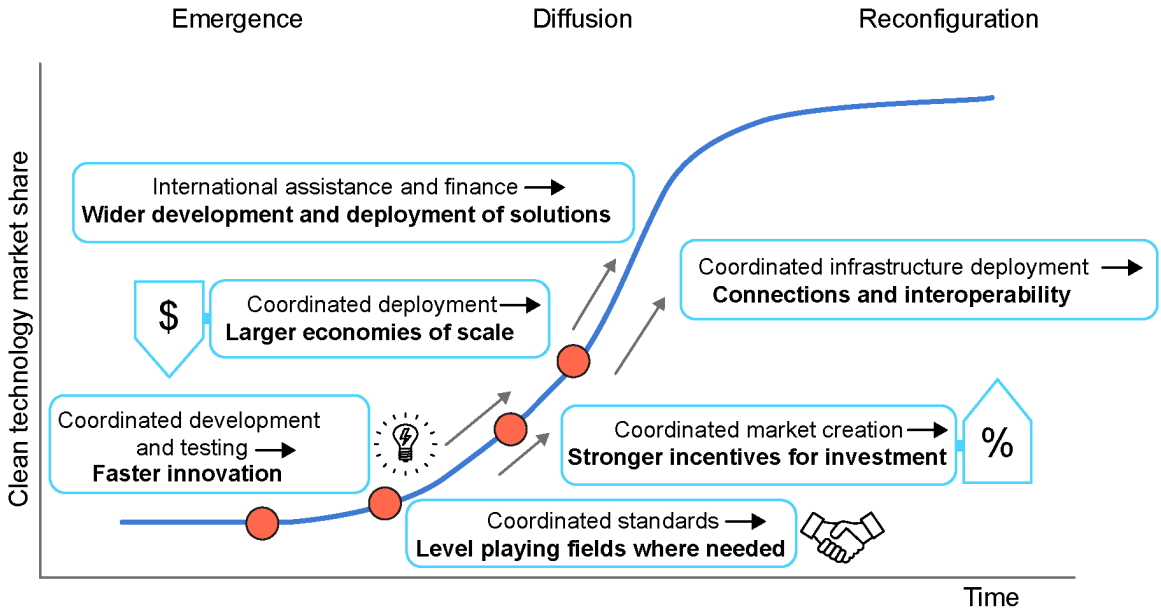
Progress on the deployment of low carbon solutions

	Indicator	2022	2030
Power	Renewables capacity	3.8 TW	11 TW
Hydrogen	Low carbon and renewable hydrogen production	0.7 Mt/yr	70 – 125 Mt/yr
Road transport	EV sales share of passenger cars	14%	At least 65%
Steel	Near zero emission steel project announcements (in 2022) vs. completed projects (in 2030)	13 Mt	At least 100 Mt
Buildings	Share of new buildings that are net zero	5%	100%
Cement	Near zero emission cement project announcements (in 2022) vs. completed projects (in 2030)	22 Mt	At least 350 Mt

Sources: IRENA (2023), World Energy Transitions Outlook 2023 (WETO); IEA (2021), Net Zero Emissions by 2050 Scenario; IEA (2023), Tracking Clean Energy Progress.

Well-targeted international collaboration is a critical enabler at each stage of the transition. Even in the current context of geopolitical and geoeconomic complexities, well-targeted collaboration can deliver important benefits. It can decrease the difficulty and amplify the effect of actions being taken individually by countries and businesses, helping to ensure a faster transition and making clean technologies and sustainable solutions more accessible and affordable to all. Its forms can include: collaborating on the development and testing of new technologies and solutions, resulting in faster innovation; coordinating deployment, delivering larger economies of scale; sending joint demand signals to create new markets, providing stronger incentives for investment; collectively improving the offer of technical and financial assistance, to enable a wider deployment of solutions; and coordinating on standards, to help create level playing fields where needed.

Figure 1 How international collaboration can accelerate progress at each stage of the transition

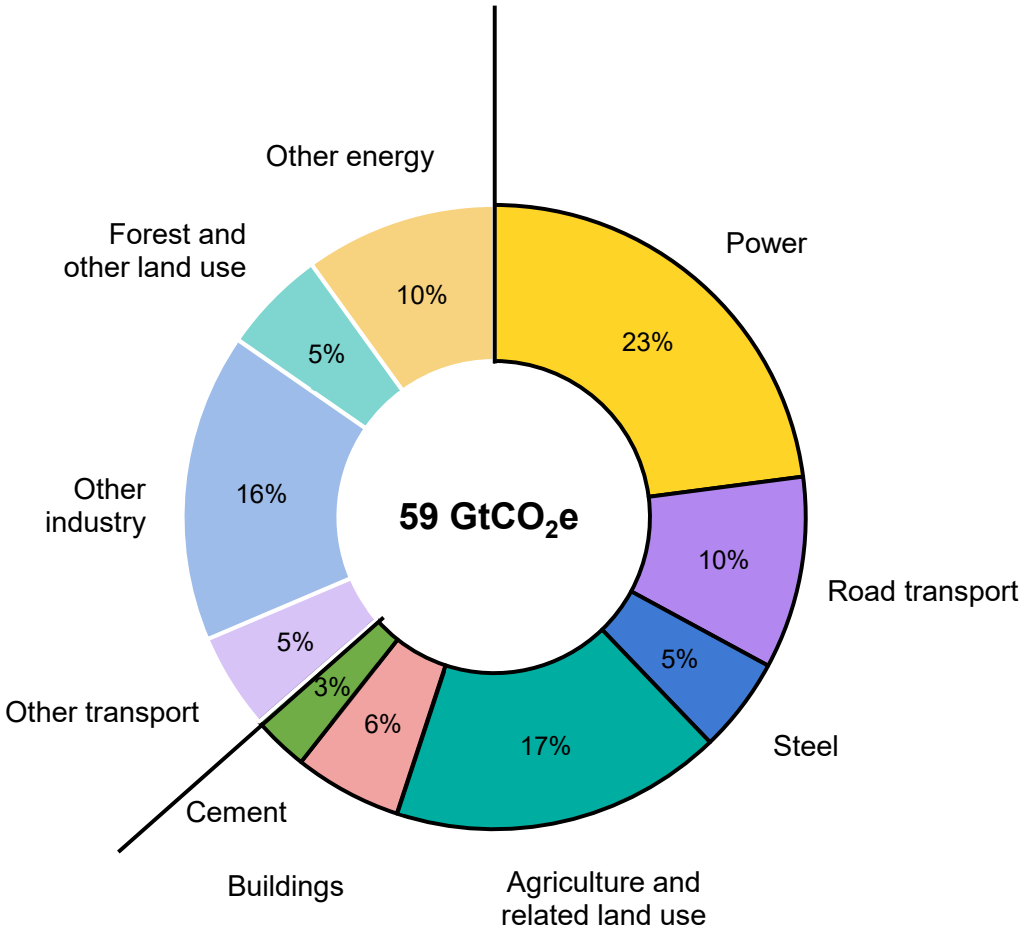


Source: Adapted from Victor, Geels & Sharpe (2019), Accelerating the Low Carbon Transition: The Case for Stronger, (Accessed 8 September 2023).

International collaboration can accelerate progress at each stage of the transition

The Breakthrough Agenda is designed to strengthen international collaboration across the major greenhouse gas emitting sectors of the global economy. The five sectors for which Breakthrough Agenda goals have already been agreed – power, hydrogen, road transport, steel and agriculture – is this year set to expand to cover the buildings and cement sectors. As a result, the Agenda will cover more than 60% of current global GHG emissions.

Figure 2 Greenhouse gas emissions by sector, 2019



Notes: Emissions are broken down by direct emissions in each sector. Only energy-related emissions from cement are included. Emissions from hydrogen production cut across several sectors. GHGs = CO_2, CH_4, F-gases, HFCs, PFCs, SF_6 and NF_3.

Source: IPCC (2022), Climate Change 2022: Mitigation of Climate Change.

The Breakthrough Agenda now covers a significant portion of global emissions.

ONLY MODEST PROGRESS HAS BEEN MADE IN STRENGTHENING INTERNATIONAL COLLABORATION ON LOW-CARBON TRANSITIONS IN THE PAST YEAR

In the past year, there has been only modest progress in strengthening international collaboration in the sectors covered in this report. Progress has been made in expanding financial and technical assistance to developing countries in some sectors (including power, road transport, hydrogen and steel) and in converging on standards for measuring emissions and defining low-carbon products (in steel, cement, and hydrogen). There has also been progress in collaborative research and development initiatives across most sectors, although there remains a need to share learning more deeply with a wider set of countries.

Much more progress is needed in aligning policies to create demand for clean technologies. In road transport, steel, cement, hydrogen, and electricity-consuming appliances, opportunities to create stronger demand signals for industry investment, and to accelerate cost reduction through economies of scale, are still being missed. Sending strong demand signals should be a high priority for international collaboration this year. There is also a need for more determined efforts to initiate dialogues on trade in sectors where this is likely to be critical to the transition, notably steel and agriculture.

Overall, current efforts remain far from exploiting the full potential of international collaboration to accelerate transitions. While participation in many initiatives has increased, in most sectors the leading international initiatives still fall short of membership that covers a majority of the global market. Greater political commitment is needed to progress from softer forms of collaboration, such as sharing best practice, to harder forms such as alignment of standards and policies, which are more difficult but can yield greater gains in mobilising investment and accelerating deployment.

Progress summary

	Standards and certification	Demand creation and management	Finance and investment	Research and innovation	Trade conditions	Other
Power						Infrastructure
Hydrogen						
Road transport						Infrastructure
Steel						
Agriculture						Knowledge and skills
Buildings						Knowledge and skills
Cement						
Cross cutting						Coordination in each sector

Note: red = minimal progress; orange = modest progress; yellow = good progress; green = strong progress; blue = new recommendation; grey = no recommendation in this area for this sector.

PRIORITIES FOR STRENGTHENED INTERNATIONAL COLLABORATION

The power sector accounts for around 13 $GtCO_2$, or 23% of total emissions. This has risen by around 10% since 2010. These need to fall by over 50% by 2030.

The average levelised cost of electricity has fallen by 86% for solar PV and 60% for wind since 2010.

By 2030, 11 TW of renewable generating capacity is required, up from less than 4 TW today.

The deployment of renewables in the **power** sector has increased to 83% of new electricity generating capacity – although the rate of annual deployment still needs to treble by 2030. There have been high profile announcements of technical and financial assistance for developing countries, but there remains a need for this to be expanded, particularly to reduce the cost of capital in developing countries, and to support the transition in the most coal-dependent regions. Collaboration on research and innovation projects should be strengthened by sharing learning with a wider set of countries. An important opportunity that remains unexploited is for countries to agree higher minimum energy performance standards for electrical appliances, to shift global markets towards more efficient products that reduce costs and cut emissions.

Emissions intensity of hydrogen production needs to fall by nearly 50% by 2030, resulting in a 10% reduction in total emissions from hydrogen production (due to the large increase in total production).

Low-carbon and renewable hydrogen production reached 0.7 Mt in 2022, compared with 70-125 Mt/yr required by 2030.

Renewable and low-carbon **hydrogen** production remained below 1 Mt/yr in 2022, compared with the 70-125 Mt/yr that is needed by 2030. There has been some progress towards convergence on standards and certification for emissions and safety, and in increasing financial and technical assistance for developing countries. A pressing need is to strengthen the collective demand signal for renewable and low carbon hydrogen, from both public and private buyers, moving from commitments and pledges to contracts and policies. The opportunity to create large-scale demand quickly is greatest in sectors where hydrogen is already used, such as fertilisers and refining. In joint research and innovation activities there is a need for greater prioritisation of those sectors where hydrogen can provide the most value, such as industry and shipping, as well as for wider geographical distribution of projects and improving knowledge-sharing.

Emissions from road transport need to fall by nearly one-third by 2030 to get on track for net zero.

The total cost of ownership of electric buses and trucks is likely to be lower than diesel counterparts across nearly all medium- and heavy-duty segments by 2030 in Europe, the United States and China.

Progress in the **road transport** sector is accelerating, with electric passenger cars now totalling 14% of total car sales, a rate that is doubling every 1.2 years. There has been progress towards taking the most polluting used vehicles out of international trade, with agreements by groups of African countries on minimum standards for imported vehicles. There has also been an expansion of technical assistance programmes in the sector. There remains a need for countries with the largest markets to agree on the pace of the transition towards all new vehicles being zero emission, and to implement this through effective policies in all vehicle segments. More progress is also needed to agree international standards for battery sustainability.

Total CO_2 emissions from the steel sector have risen since 2015, before stabilising since 2019.

In the **steel** sector, nearly 90 Mt of new high-emission blast furnaces are anticipated before 2025. Announcements for new near-zero emission steel plants have increased to 13 Mt, more than doubling versus last year, but still far short of the more than 100 Mt needed by 2030. There has been good progress in aligning emissions accounting methodologies and definitions for near-zero emission steel, and modest progress in the delivery of financial and technical assistance for developing countries,

The project pipeline for primary near-zero emission plants has increased to 13 Mt, from 5 Mt last year. Over 100 Mt is required by 2030 to get on track for net zero.

Agriculture emissions continue to increase to 7.3 $GtCO_2$ in 2022. They need to fall to 5.7 $GtCO_2$ to get on track for net zero.

Gains and losses in global cropland are roughly equal, although agricultural expansion continues to drive deforestation. Expansion will have to stop completely if 2030 targets are to be met.

Buildings sector emissions represent around a third of total energy system emissions. Operational emissions need to fall by about 50% from their 2022 level by 2030, to get on track with net zero.

80% of the growth in buildings floor area through 2030 is set to take place in emerging and developing economies.

Emissions intensity of cement production has risen by nearly 10% since 2015, largely due to an increase in the clinker-to-cement ratio in China.

By 2030, around 10% of global cement production capacity needs to be consistent with near-zero emissions.

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with the launch of new funds. There is an urgent need for stronger collective efforts to create demand for near-zero emission steel: while participation in public sector initiatives for this purpose has risen (from 9% to 20% of the global market), purchase commitments of the kind that could mobilise industry investment at scale have not yet been made. Other priorities are to increase the sharing of learning from early demonstration projects with developing countries, and to expand initial discussions on trade and the steel transition to include the largest steel producers in emerging economies.

In **agriculture,** emissions remain on a long-term upward trend, crop yields are not improving at the rate needed, and agricultural expansion continues to drive deforestation. While there have been some new international commitments to investment in research and development, there remains a need for increased development assistance, sustained and substantial policy exchanges, and cooperation on standards and trade. This need is most pressing in relation to sustainable agriculture solutions with proven effectiveness, which could be more rapidly deployed, including agroecology and other sustainable approaches, low emission fertilisers, alternative proteins, crop and livestock breeding, measures to reduce livestock methane emissions, reductions in food loss and waste, and digital agriculture and climate services for farmers.

Emissions in the **buildings** sector have grown at an average of 1% per year since 2015, with the global growth in floor area more than offsetting the increased efficiency and decarbonisation efforts. Mandatory building energy efficiency codes are a key national policy, requiring a scale-up in technical assistance to ensure all countries have them in place. International agreements on definitions and standards that support the comparability and interoperability of these codes can help facilitate private investment. Aligned public procurement commitments for zero emission buildings can help grow markets for new construction methods, materials and building appliances, even though some of the coordination gains may be limited by the highly localised nature of the sector. More accessible technical assistance for developing countries is needed to support policy design and implementation, and to facilitate investment.

Total emissions in the **cement** sector have been rising since 2015, although there has been a wave of recent announcements of large projects for near-zero emission cement production. Most of the key technologies required have not yet been deployed commercially at scale. Private sector collaboration on research, development and demonstration has been notably substantial. As in the steel sector, the urgent need is to complement this with strong collective action to create demand for the near-zero emission product, and while countries and companies have recently joined initiatives with this intent, they have yet to convert the intention into effective action. It will also be important to ensure that knowledge from early demonstration and commercial-scale projects is shared quickly with a wide range of countries, to accelerate wider build-out.

In terms of **cross cutting** collaboration that will have an impact in several sectors, progress has been most notable in research and innovation, where countries have committed USD 94 billion to clean energy demonstration projects by 2026. On finance, the Bridgetown Initiative has prompted discussions at heads of government level on proposals to reduce the cost of capital for developing countries' investments in clean technologies, and there has been some progress in the development of platforms to match developing countries' needs with international investment and technical assistance. On trade, the Climate Club has taken initial steps towards coordinated international action on industrial decarbonisation but has so far only involved two of the ten largest emerging economies; expanding participation will be important to the effectiveness of these efforts. There has been some progress in clarifying the structure for international collaboration within each sector, with the Breakthrough Agenda process contributing to the coordination of activities and providing clearer direction where participation or resources need to be increased.

Other sectors: opportunities to improve international collaboration and make low-carbon transitions less difficult are likely to exist in sectors not yet covered by the Breakthrough Agenda. These include shipping, aviation, and industrial sectors other than steel and cement (such as chemicals and plastics).

In many sectors there will be synergies between actions to reduce emissions and actions to build resilience. The agreement at COP 27 of the Sharm El Sheikh Adaptation Agenda, to be advanced in parallel with the Breakthrough Agenda, creates an opportunity for these synergies to be enlarged and accessed more widely through well targeted international collaboration. In January 2023, the COP 28 Presidency announced a partnership with the Breakthrough Agenda, which has the potential to strengthen international cooperation by providing greater continuity of efforts between COPs, especially if emulated by future COP Presidencies.

The summaries of progress in each sector outlined below demonstrate the contribution that international collaboration is already making to accelerate the transition. Often, action in one sector contributes to progress in another, such as by speeding up the deployment of key technologies. The priorities for action and recommendations in each sector provide a clear pathway to continue accelerating the transition.

Power progress summary

Area	What progress has been made?	What more needs to be done?	2023
P2. Finance and investment	• A wave of new public and private commitments, including JETPs. • The development of innovative financial instruments improving access to finance. • Further growth in matchmaking platforms to improve access to assistance.	• Continue to increase the scale of public and private investments. • Increase public commitments, channelled through direct investments, blended finance, and other instruments such as grants and subsidies to help reduce the cost of capital in developing countries. • Improve collaboration around successful de-risking mechanisms, particularly among MDBs and other lenders.	Modest
P3. Social engagement	• Several support programmes announced focused on the social aspects of the transition. • Improvements in capacity building for government officials and local industries.	• Align development funding with targeted support for economic diversification in fossil fuel dependent regions. • Develop strategies to strengthen local supply chains, using local expertise and international best practice. • Share learning among countries and support the creation of dedicated national social task forces.	Minimal
P4. Research and innovation	• Increase in the participation in key public and private sector initiatives. • Countries have set out joint innovation priorities and plan for demonstration projects in all regions. • Strengthened collaboration and knowledge exchange among the initiatives working in this area.	• Better co-ordinate efforts to research, develop and demonstrate technologies, particularly across emerging markets. • Prioritise R&D investments in key enabling technologies, such as storage, distributed energy resources and system operation. • Assess prospects for the refurbishment and repurposing of existing assets such as hydropower units and thermal power plants.	Modest
P5. Infrastructure	• Countries have set clear priorities and roadmaps for regional grid initiatives. • Advanced bilateral and regional initiatives to implement or improve cross-border power exchange. • Improved knowledge exchange between regulators and other relevant actors.	• Collectively identify mechanisms to mitigate security of supply risks for cross-border infrastructure. • Explore means of reducing transaction costs and fast-tracking permitting. • Scale up manufacturing capacity to reduce current market lead time and avoid shortfalls of key materials.	Modest
P6. Demand management	• Increased membership of efficiency and energy standards initiatives. • A modest increase in in-country assistance and technical capacity building.	• Countries to collectively agree to higher minimum energy performance standards for high energy-consuming appliances. • Improved technical and financial assistance to facilitate the application of measures.	Minimal

Power recommendations	
1	Governments, working with key institutions, and funds, should ensure that international support is available at better terms, including grants at early investment stages. That includes creating de-risking mechanisms, tailored to the country's respective contexts, helping to mobilise private sector investments. Overall provision of resources should be increased, particularly towards technologies that have not achieved commercial maturity.
2	Governments and MDBs should work together to more strongly align development funding with targeted support for local jobs, skills and investment, for the repurposing of fossil fuel assets, economic diversification, and for environmental restoration, in fossil fuel dependent regions and communities. Civil society, governments and industry should contribute to creating international centres of expertise on the just transition, within existing institutions.
3	Governments should work through relevant initiatives to accelerate the identification of suitable demonstration projects, resource them appropriately, and ensure high-quality knowledge-sharing structures are put in place. To facilitate knowledge sharing among a wider set of countries and stakeholders, close collaboration with regional research and innovation networks will be required.
4	Governments should work together to reassess the opportunities for cross-border and regional power interconnection and smart grids to support the transition to clean power systems, including opportunities that have been previously considered but not taken forward, given the improving technology, falling costs, and increasing need for system flexibility. Countries and investors should support international efforts to identify top regional priorities for interconnection, and to replicate successful approaches to technical agreements.
5	Countries, in consultation with industry, should collectively agree to higher minimum energy performance standards for high energy-consuming appliances, supported by awareness campaigns and incentives, such as energy efficiency retrofit programmes. Improved technical assistance should facilitate the implementation of effective standards in developing countries.

Hydrogen progress summary

Area	What progress has been made?	What more needs to be done?	2023
H1. Standards and certification	• IPHE leading major efforts on methodologies, in partnership with ISO, and increasingly co-ordinating the wider landscape. • IEA Hydrogen TCP has set a task on certification harmonisation. • Other assessments or relevant work from IRENA and RMI, the European Clean Hydrogen Alliance and the Hydrogen Council.	• Prepare a well-articulated plan that defines resource needs for the development of a comprehensive portfolio of standards. • Provide appropriate resources to undertake the relevant work on standards development. • Governments to work through existing forums to ensure methodologies used to define regulatory frameworks are interoperable.	Modest
H2. Demand creation	• Notable individual efforts from countries, albeit lacking international coordination on near-term commitments and policies. • The IRENA Collaborative Framework on green hydrogen has established a workstream on understanding how to co-ordinate demand and supply globally.	• Increase the strength of the demand signal by moving from commitments and pledges to contracts and policies. • Improve co-ordination of efforts by more countries and companies working through joint initiatives.	Minimal
H3. Research and innovation	• Commitment to establish a conceptual framework to exchange best practices by COP 28. • The Hydrogen Valley Platform had identified 83 projects from 33 countries by July 2023.	• Ensure new projects are focused in priority sectors and increase geographical diversity of demonstration projects. • Increase efforts to establish proactive knowledge-sharing platforms and processes between lead projects.	Minimal
H4. Finance and investment	• UNIDO, World Bank and IRENA mapping currently available assistance and financing best practice, to support an improved offer. • The Hydrogen for Development Partnership was launched by the World Bank, to help catalyse funding for projects in developing countries through providing improved in-country support.	• Governments to work with IFIs to identify projects that are being delayed by high costs of capital and other obstacles to investment, then identify best practices to support targeted and tailored technical assistance for policy design.	Modest

Hydrogen recommendations	
1	Governments and businesses should provide financial and human resources for the development and implementation of a comprehensive portfolio of national and international standards, based on a well-articulated plan that defines resource needs. Governments should also work towards the adoption of a common methodology to calculate the carbon footprint of the hydrogen value chain to facilitate mutual recognition and interoperability of certification systems. Governments, especially those of developing countries, should anticipate building technical capacity of their national systems to verify compliance with international hydrogen standards.
2	Governments and companies should co-ordinate internationally to increase commitments for the use of low-carbon and renewable hydrogen in sectors where hydrogen is already used, supported by specific policies and purchase agreements, to collectively send a strong demand signal and mobilise investment in production. In new priority application sectors, countries should share learning to accelerate early deployment. This should be done in a manner that ensures a level playing field in international trade.
3	Governments and companies should work together to dramatically increase the number and geographical distribution of hydrogen demonstration projects and to ensure that these appropriately cover each of hydrogen's high-value end-use sectors, including maritime shipping, heavy industry and long-duration energy storage. Governments and the private sector should agree on minimum reporting principles to guide a deeper and more rapid sharing of knowledge among these demonstration projects and with the broader stakeholder community, including a commitment to share the lessons learned from all publicly funded demonstration projects.
4	Governments, MDBs and relevant technical partners should work to identify viable projects that are being delayed by high costs of capital and other obstacles to investment, then identify best practices to help unlock their progress. This should be supported by appropriate technical assistance programmes to assist governments with policy design for the further scale-up of projects.

Road Transport progress summary

Area	Progress highlights	What more needs to be done	2023
Long-term vision	• Increased membership of multiple initiatives setting voluntary commitments for zero emission vehicle (ZEV) adoption. • Notable expansion of commitments beyond electric cars, including 5 corporate members of EV100+ and 14 corporate members of FMC Trucking.	• Translate voluntary commitments into binding policies for all major markets and secure broader support from original equipment manufacturers (OEMs). • Expand commitments into new vehicle segments, including 2- and 3-wheelers.	Modest
Finance and investment	• ZEV-Transition Council (ZEVTC) International Assistance Taskforce (IAT) and the Collective for Clean Transport Finance providing mapping and technical assistance, with a particular focus in Sub-Saharan Africa and India. • Expansion of technical and financial assistance, notably via the GEF-7 Global Electric Mobility Programme and the World Bank's Global Facility to Decarbonise Transport.	• Scale up support globally, including in product supply, policy and standards, through stronger co-ordinated working. • Further co-ordinate to scale, accelerate and de-risk investment, reduce cost of capital, and mobilise companies. • Countries should better track project-level key performance indicators to guide future policies and assistance efforts.	Modest
Supply chains	• Co-ordination on EV battery supply chain sustainability by the Global Battery Alliance (GBA) • UNECE developing methodology for measuring GHG emissions, covering the entire automotive life cycle.	• Greater global harmonisation of sustainability standards (i.e. battery carbon footprint, responsible sourcing) and common, interoperable standards for digital product passports (i.e. data governance). • Support data & research on key obstacles and policies for enhancing circularity in battery value chains.	Modest
Infrastructure	• Establishment of ZEVTC taskforce to facilitate collaboration on charging infrastructure deployment. • ZEVWISE Coalition sharing knowledge and expertise in the medium- and heavy-duty segments, including infrastructure deployment and financing.	• Agree on a set of priority areas for scaling up technical and financial assistance and design an implementation plan for delivery. • Design regional roadmaps that lay out the needs for infrastructure deployment for trucks and buses.	Modest
Trade conditions	• UNEP given a formal charter by the UN Environment Assembly to pursue policy-oriented data collection and research on used vehicle quality standards.	• Exporting and importing countries should convene to agree on an international harmonised framework on minimum standards on used vehicles, and establish a publicly accessible database for tracking.	Good

Road transport	
1	Governments should agree on a timeline by which all new road vehicle sales should be zero emission, with interim targets for countries taking into account their level of economic development and ability to scale up infrastructure. Governments should put effective policies in place to implement these commitments. Targets should be Paris-aligned and should include all vehicle types.
2	Governments and international organisations should increase low-cost financing and dedicated funding to projects to accelerate ZEV adoption in EMDEs, focusing on ensuring that EMDE countries are aware of and have ready access to technical assistance and financing offers, and ensuring the effectiveness of project delivery and policy development support.
3	Governments should work together to agree on harmonised sustainability standards and metrics, including battery carbon footprint, responsible sourcing and broader environmental, social and governance risks and impacts wherever possible. In the context of digital product passports, they should work towards enabling global interoperability, including harmonised data governance (i.e. data collection, management, assurance and verification standards). Further, governments should jointly address priority areas for sustainable value chains including transport, trade and recycling bottlenecks for battery materials at the end of life, circularity-based product design and processing, and technical assistance for developing markets and emerging economies on EV battery end-of-life management.
4	Governments should agree to further increase technical and financial assistance to support charging infrastructure. Governments and companies should support and leverage the mechanisms established for sharing best practices, knowledge, and relevant technology, and for supporting implementation by countries and Non-State Actors at national and regional levels.
5	Exporting and importing countries should agree on minimum standards for cross-border trade of used vehicles. Countries should establish a publicly accessible database for tracking cross-border used vehicle trade. Governments and companies should develop strategies to define and legislate quality standards, enforced at ports of export and defined based on standards established by importing countries, for used Internal Combustion Engine (ICE) vehicles, as well as commitments to support the international trade of second-hand ZEVs, and publish plans by COP 28.

Steel progress summary

Area	What progress has been made?	What more needs to be done?	2023
S1. Standards and definitions	• Increase in membership of and co-ordination between key public and private sector initiatives. • Emerging consensus on emissions accounting methodologies. • Growing convergence on definitions for 'near-zero emission steel'.	• Achieve broad consensus on methodologies by end 2024. • Agree process for verifying 'near-zero emission' claims. • Accelerate adoption of standards in national policy through collaboration between countries.	Good
S2. Demand creation	• Increase in membership of key public and private sector initiatives, with CEM IDDI growing from countries representing 9% to 20% of global steel production. • Increased efforts to engage regions outside Europe and North America.	• Move from commitments and pledges to contracts and policies. • Agree to share procurement data to strengthen demand signal.	Modest
S3. Research and innovation	• Growing number of successful private sector collaboration models for steel. • Initial bilateral country partnerships being established under Mission Innovation NZIM.	• Scale up country-level collaboration, making best use of private sector models where possible. • Work closely with climate finance funds to build engagement with developing countries.	Modest
S4. Trade conditions	• Some initial progress within new and existing forums and agreements, such as the WTO, OECD, Climate Club and GASSA.	• Establish a dialogue on steel decarbonisation policies and trade, involving all major steel producing and consuming countries.	Modest
S5. Finance and investment	• Launch of new funds, such as CIF Industry (USD 80 million out of USD 500 million capitalised). • Initial interest to improve the effectiveness of delivery, including from LeadIT and the Climate Club.	• Establish a matchmaking platform to link supply and demand for assistance and build sectoral expertise among major IFIs. • Donor countries to further increase commitments for industry decarbonisation funds.	Modest

Steel recommendations	
1	Governments and companies should work through existing collaborative forums to align emissions accounting methodologies for steel by the end of 2024. Countries representing the majority of global steel production should commit to adopting net zero compatible mandatory standards from the mid-2020s. Appropriate steps should be taken to clarify the compatibility of emerging definitions with net zero.
2	Governments and companies should increase the scale of near-zero emission steel procurement commitments to cover a significant share of their future steel demand, joining relevant public and private sector initiatives where these commitments are aggregated. These commitments should be high quality and should be supported by appropriate legal and implementation frameworks, such as advance purchase commitments.
3	Governments and companies should collaborate via existing initiatives to fast-track sharing of technology learning, business case development and policy support to accelerate the development of pilot projects. Emerging markets and developing countries' participation in key RD&D initiatives should be increased in support of this aim.
4	Governments should urgently launch a strategic dialogue on trade and the steel sector's transition, including the leading producer and consumer countries, with the purpose of agreeing ways to ensure near-zero emission steel can compete in international markets. This is needed to ensure that trade helps to accelerate the transition and does not hold it back.
5	Countries should establish an improved matchmaking function focused on industry decarbonisation and including steel that can better respond to developing country requests for financial and technical assistance. This should include donor countries, recipient countries, IFIs, national development banks, philanthropic organisations, private financial institutions and companies, with regular meeting of ministers.

Buildings progress summary

Area	Progress highlights	What more needs to be done	2023
B1. Standards and certification	• Whole-life carbon assessments exist in many countries, mostly voluntary. There is a limited availability of resilience assessments frameworks. • Some limited collaboration among developed countries and some private sector organisations to advance compliance with standards and associated certification.	• Governments to harmonise and upgrade definitions of near-zero and resilient buildings, defining and using a common set of concepts and nomenclature. • Governments to align frameworks for whole-life carbon assessments and data collection and define resilience assessments.	New
B2. Demand creation	• Strong aggregated procurement campaigns and policy commitments focused on building appliances and materials, albeit not for heating and cooling and whole building or-project-level. • A broad representation of international private sector initiatives, with public sector collaboration at an earlier stage.	• Governments to work in partnership with existing forums to aggregate and amplify the demand signal for net zero and resilient buildings, expanding public sector participation and commitment. • A greater focus on whole building procurement commitments, covering materials, appliances and construction.	New
B3. Finance and investment	• Investment in energy efficiency and electrification for buildings at an all-time high, but not yet on track for net zero emissions by mid-century, and already showing early signs of slowdown. • Some engagement of IFIs and business in unlocking private sector investment through several forums, although it is still challenging to match requests for support with the right funding and technical partners.	• Governments should increase the scale of financial and technical assistance made available for developing countries. • Improved co-ordination of IFIs and private sector investments to target flagship projects which can then unlock major pipelines of projects in emerging and developing economies in particular.	New
B4. Research and deployment	• Several well-established collaborative R&D forums already exist – with success in major technologies, such as heat pumping technologies, superinsulation and ventilative cooling. Current forums can be strengthened and expanded to increase and accelerate the impact of research and innovation.	• Governments to co-ordinate on research, development and demonstration priorities to understand knowledge gaps, which can be overcome via joint working. • Accelerate the creation of joint programmes to test and demonstrate new technologies, supporting developing country involvement.	New
B5. Capability and skills	• Several collaborative forums deliver successful training programmes for construction and engineering roles that will be vital for the buildings sector and can be strengthened to build capacity and skills to deliver net zero and resilient buildings.	• Countries and companies should jointly define training and capacity-building priorities, strengthening the role of existing networks to provide guidance, tools and resources for curriculum design, as well as international accreditation for education and training. • Countries should focus on delivering technical capacity for the implementation and upgrade of building energy codes in countries where most growth in floor area is forecast.	New

Buildings recommendations	
1	Governments should work together to harmonise and upgrade the definitions and nomenclature for net zero and resilient buildings and their performance. Countries should work towards harmonising whole-life carbon assessments, developing resilience assessments, and aligning certification scheme with net zero and resilient requirements. Harmonisation should permit the flexibility to accommodate different regional contexts and should be supported by establishing shared international mechanisms, platforms and formats for data sharing of best-in-class net zero and resilient projects.
2	Governments should jointly create and strengthen procurement commitments for net zero and resilient buildings, as well as joining existing low-carbon material procurement alliances. Countries should work to establish new joint commitments on deploying clean and efficient heating and cooling technologies.
3	Countries should increase the scale of funding available for net zero and resilient building projects as well as improving the co-ordination of assistance going forward through the establishment of a establish a matchmaking platform dedicated to the delivery of net zero and resilient building projects. This platform would act as a single point of contact for emerging and developing countries, with support from donor countries, MDBs, NDBs, private financial institutions and investors, philanthropic organisations, buildings and real estate companies and technical assistance partners.
4	Countries and companies should work together to identify knowledge gaps that can be overcome via joint working, and align RD&D priorities to shared policy goals. Countries should also facilitate the expansion of existing networks to bring in new expertise and country members, and work through those networks to improve communication of high-quality research and best practice, deliver training to deploy innovative technologies, construction practices, tools and business models at scale, using government projects to lead the way.
5	Countries and companies should jointly identify knowledge gaps and define training and capacity-building priorities, strengthening the role of existing networks to share knowledge and provide guidance, tools, and resources to build capacity across all regions. This includes a focus on supporting developing countries with implementing and increasing the stringency of building energy codes. Countries should also work together to assist in curriculum design, implementation of training programmes and accreditation frameworks to enhance the transferability of skills and qualifications, and ultimately promote net zero and resilient building practices.

Cement progress summary

Area	Progress highlights	What more needs to be done	2023
C1. Standards and certification	• Strong alignment between international organisations on production level emissions accounting. • Countries and companies increasingly looking to define low and near-zero emission cement and concrete.	• Countries should agree a timeline for developing and adopting 1.5 C aligned low and near-zero emission definitions, as well as guidelines for efficient use and reuse of building material.	New
C2. Demand creation	• Several, relatively new public and private sector forums for aggregating demand-side commitments.	• Further scale-up of high-quality commitments, which should be multi-year and backed by offtake agreements and or policy support.	New
C3. Research and innovation	• Successful private sector collaborations are well-established, focused on both pre-competitive and applied innovation. • Recent launch of MI NZIM to support country-level collaboration.	• Accelerate the pace of learning among a wider set of countries, linking efforts to available financial and technical assistance. • Support the delivery of pilot and demonstration scale projects for deep decarbonisation technologies.	New
C4. Finance and investment	• Several IFIs have programmes in place which can support cement decarbonisation projects. • A growing focus from countries to improve the financial and technical assistance offer for developing countries, including under the Climate Club and LeadIT.	• Develop an improved matchmaking function focused on industry decarbonisation to better respond to developing country requests and mobilise private sector investment.	New

Cement recommendations	
1	Countries and companies should work through existing collaborative forums to agree definitions for low and near-zero emission cement and concrete by the mid-2020s, as well as guidelines for the efficient use and reuse of building material.
2	Countries and companies should work through existing collaborative forums to co-ordinate and scale up early efforts to create a market for near-zero emission cement, including via high-quality, multi-year purchase commitments and/or policy support.
3	Countries should work together with effective private sector collaborative forums to accelerate the pace of learning between a wider set of countries, with a particular focus on developing countries. These partnerships should support the delivery of pilot and demonstration scale projects in all major emerging and developing countries well in advance of 2030.
4	Countries should establish a matchmaking function focused on industry decarbonisation and cement that can better respond to developing country requests for financial and technical assistance. In addition to participating countries, this should include IFIs, national development banks, philanthropic organisations, private financial institutions, industry coalitions and companies, with regular meeting of ministers.

Agriculture progress summary

Area	Progress highlights	What more needs to be done	2023
A1. Finance and investment	• New analysis and roadmaps for climate finance expected at COP 28.	• Overall levels of finance for agrifood systems need to substantially increase, after falling over 2021. • Additional finance should focus on priority areas, such as agroecology, reduction of food loss and waste, reducing methane emissions and crop and livestock breeding.	Minimal
A2. Knowledge and skills	• The Policy Dialogue on Transition to Sustainable Agriculture continued to convene governments to share best practice on policy reform. • The Africa Agriculture Policy Leadership Dialogue brought together key stakeholders in 2023.	• Accelerated sharing of best practice policies among countries who make up the majority of agrifood markets. • Provision of high-quality evidence and analysis to better inform discussions among countries.	Modest
A3. Standards and certification	• Regional agreements across some agrifood metrics exist (e.g. in the European Union) but there is no consensus globally.	• Development of internationally agreed standards for monitoring and reporting on the state of natural resources.	Minimal
A4. Research and innovation	• An increase in funding commitments for R&D delivered through the Agriculture Innovation Mission for Climate (AIM4C).	• Working with key development partners, increase the level of R&D funding supporting projects in developing countries.	Modest
A5. Trade conditions	• The World Trade Organization (WTO) participated in the Agricultural Ministers' Conference at the 15th Global Forum for Food and Agriculture.	• International agreements on standards and trade to provide investor and business confidence. • Improved information for consumers on traded products' sustainability.	Minimal

Agriculture recommendations

1	Increased climate finance should be directed to supporting the deployment of agricultural technologies and approaches for which science has generated evidence on effectiveness, including agroecology, reducing food loss and wate, reducing livestock methane emissions, reducing emissions from fertilisers, and crop and livestock breeding.
2	Governments, research institutions, international organisations and the private sector should commit to a long-term process to test, develop evidence and share learning on policy and implementation. This should prioritise the redirecting of subsidies to support agriculture to move towards sustainability and climate resilience, and the facilitation of faster uptake of proven technologies in the sector.
3	Governments, international organisations and research institutes should develop common metrics and indicators to track the adoption of key sustainable agriculture solutions and to monitor the state of natural resources on which agriculture depends.
4	Governments, research organisations and companies should work together to deliver higher levels of investment in agricultural research, development and demonstration, to be maintained over the course of this decade. Priority should be given to innovations that can reduce methane emissions from livestock, make alternative proteins a reliable and affordable option, increase the resilience of crops, and advance uptake of digital services by farmers.
5	Governments should begin strategic dialogues on how to ensure international trade facilitates, and does not obstruct, the transition to sustainable agriculture. In addition to addressing the agricultural commodities that contribute disproportionately to deforestation, early priority should be given to agreeing standards, labels and regulations for alternative proteins, low-emission fertilisers, and products of agroecological and other sustainable approaches, and to developing intellectual property frameworks that promote access to resilient and low-emission crop and livestock varieties. This should be complemented with international sharing of best practice on mobilising private investment and engaging consumers.

Cross cutting progress summary

Area	Progress highlights	What more needs to be done	2023
Co-ordination in each sector	• The Breakthrough Agenda has started to facilitate improved collaboration between countries, companies and civil societies in several sectors. • Landscape maps have become a vital tool to communicate the range of activity in each sector.	• Secure greater participation, both in terms of the membership and engagement. • A more consistent provision of resources to fund necessary collaborative work, support engagement of vital stakeholders.	Good
Finance and investment	• Establishment and further development of sectoral matchmaking platforms. • Coordinated calls to improve the global financial architecture.	• A focus also on inter-sectoral coordination. • Greater country engagement required to accelerate the process of MDB reform in line with calls from developing countries.	Modest
Trade conditions	• Early progress to build open and inclusive forums for strategic dialogues on trade-intensive products. • Growing interest from the WTO and members to engage in trade and sustainability discussions.	• Countries need to accelerate their commitment to establishing high-level dialogues on major issues, such as carbon leakage and other risks for mitigation efforts, ensuring representatives from all major markets.	Minimal
Research and innovation	• Commitment of USD 94 billion for clean energy projects and 221 demonstration projects committed to under Mission Innovation.	• Greater focus on developing country projects, making best use of private sector models, in close collaboration with IFIs.	Modest
Standards and definitions	• ISO Net Zero Guidelines and UN High Level Expert Group provide useful guidance on compatibility with net zero.	• Establishment of an international function to better verify claims, making use of detailed sectoral expertise.	New

Cross cutting recommendations	
1	Countries should further strengthen forums and institutions that support international co-operation in each sector, with increased political and financial support, sufficient participation, and deeper analysis and communication of the potential gains from co-ordinated international action.
2	Governments, financial institutions, philanthropic organisations and delivery partners should continue to improve the co-ordination of technical and financial assistance in each sector, learning from existing successful models. Further efforts are required to improve the conditions and delivery of financial assistance, in line with developing country requests.
3	Governments, companies and relevant international organisations should establish high-level, strategic dialogues in each sector that is highly exposed internationally and where uneven competition risks being a barrier to the transition, to develop a common approach to reaching a level playing field. This should include, where relevant, actions on data, standards, procurement, technology collaboration and technical and financial assistance, as well as trade.
4	Governments and companies should greatly increase spending on clean technology demonstration projects, working together to bring new technologies to commercial-scale deployment as soon as possible. Early deployment projects should be supported by matchmaking forums and ensuing commitments and processes in all regions.
5	Wherever not already agreed, governments in each region of the world should agree to the top priority common infrastructure projects that can support near-term growth in the deployment of clean solutions, such as interconnectors and hydrogen pipelines. In each of the land, sea and air transport sectors, countries and companies should identify specific international routes to be prioritised for the co-ordinated first deployment of zero-emission charging or refuelling infrastructure.
6	Building on existing international efforts, governments should consider the establishment of an international function to improve the collective verification of claims of different standards and their compatibility with international climate goals, across multiple sectors.

CHAPTER 1. INTRODUCTION

THE STATE OF THE TRANSITION

The past year has seen an acceleration of the global energy transition in many sectors, spurred by the global energy crisis and ongoing recovery from the Covid-19 pandemic. Total investment in energy transition technologies reached a record high of USD 1.3 trillion in 2022, increasing 19% since 2021. Renewable electricity capacity additions are expected to increase to more than 440 GW over 2023, with solar PV accounting for two-thirds of this growth. Looking forward, if all announced projects are realised, solar PV manufacturing capacity will comfortably exceed the deployment needs of the IEA's Net Zero Emissions by 2050 Scenario (NZE Scenario) in 2030. Similar success can be observed in the deployment of electric cars, which have been doubling every 1.2 years and currently stand at 14% of total car sales. At this rate, the deployment of electric cars is aligned with what is required under a net zero scenario.

Much of this activity has been turbocharged by major new policies from governments – partly in response to the global energy crisis – and this is set to continue. This includes the US Inflation Reduction Act, the EU's REPowerEU and Fit-for-55, Japan's Policy for the Realization of Green Transformation, India's Production Linked Incentive (PLI) scheme and People's Republic of China's (hereafter, "China") Latest Five-Year-Plan (2021-2025). Whilst these are likely to result in a further acceleration of the global energy transition, significant challenges remain.

Global energy-related CO_2 emissions still grew by 1% in 2022, at a time when they need to fall on average by around 6% each year. Progress in emerging markets and developing countries is lagging further behind, with additional headwinds from the changing geopolitical context. Moreover, even among advanced economies, faster progress is still needed. By 2030, the rate of deployment in renewables needs to treble according to the IEA and IRENA, annual heat pump sales need to increase fivefold and the deployment of near-zero emission industrial facilities – which has barely started today – needs to accelerate significantly.

In terms of investment, more than 90% of the increase in clean energy[1] that took place over 2022 occurred in advanced economies and China. IRENA's Global Landscape of Renewable Energy Finance shows that more than 50% of the world's population, mostly residing in developing and emerging countries, received only 15% of global investments in renewables in 2022. The share of renewable energy investments going to these countries

[1] 'Clean energy' includes renewable power, energy efficiency, grids, electric vehicles, battery storage nuclear, low-emission fuels and carbon capture, utilisation and storage.

has been progressively declining year on year. Whilst investment in solar is set to overtake oil for the first time in 2023, total fossil fuel investment still stands at over USD 1 trillion, rising from a low in 2020.

THE ROLE OF INTERNATIONAL COLLABORATION

In the Breakthrough Agenda Report 2022, we set out how international collaboration would be essential to achieving faster innovation, larger economies of scale, stronger incentives for investment and – where needed – level playing fields. In this year's report, we dive deeper into many of these areas, considering progress in the past 12 months and using this assessment to inform our advice for governments, business and civil society.

This includes the role of co-ordinated low-emission and near-zero emission standards across hydrogen, steel and cement; the opportunity for aggregated and aligned demand signals in those same sectors and also for sustainable building materials and end-use appliances; the need for co-operation on trade for used vehicles, steel, and agricultural commodities; and the role of deeper sharing of learning from research and development in key technologies to support the transition in all sectors.

We've observed progress in the level of ambition, participation and resources committed to collaborative efforts in some of these areas over the past year, but in others there has been little visible change. A more determined international effort in each sector is clearly needed to increase the pace of the global transition.

THE BREAKTHROUGH AGENDA

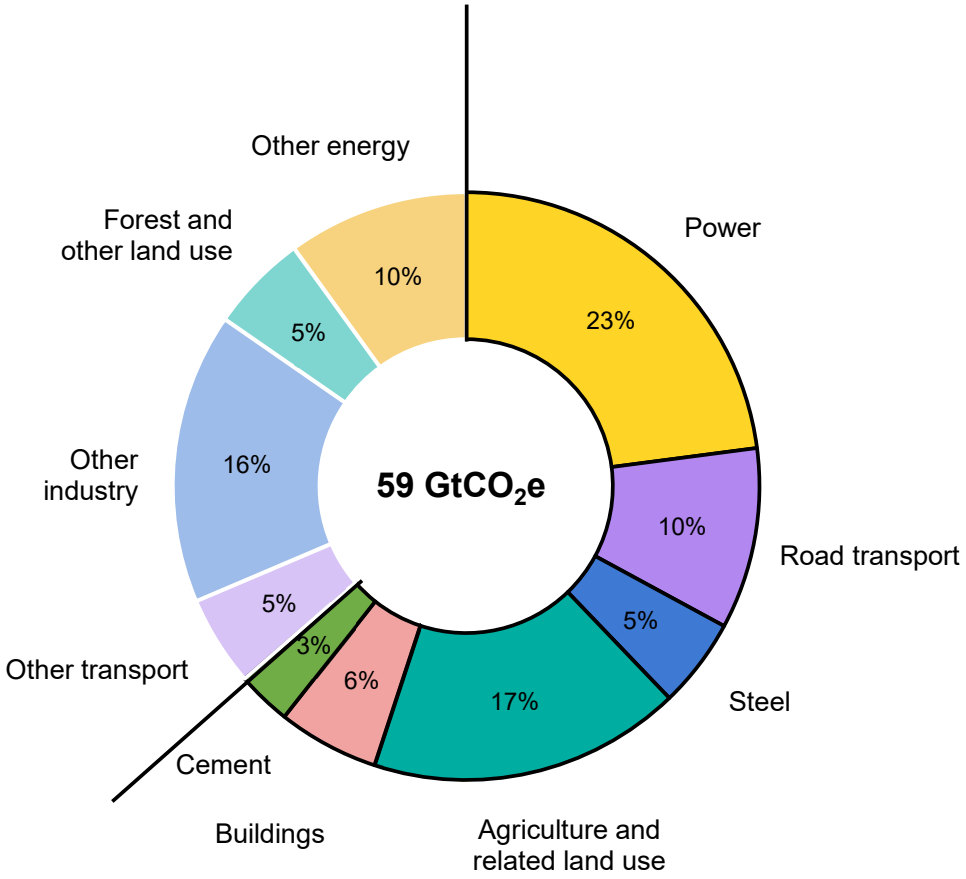
Since last year, countries supporting the Breakthrough Agenda have begun to embed its role as an important co-ordinating process helping to strengthen international collaboration within major emitting sectors. In each of the sectors covered by the Agenda, groups of countries and sector-specific initiatives have met regularly over the past year to advance their shared understanding of the collaborative efforts that are already in progress, and of the steps that need to be taken next.

Membership of the Breakthrough Agenda has increased to 47 countries, now totalling over 80% of global GDP. Beyond this, membership of the sectoral Breakthroughs has increased, with both new countries and additional collaborative forums and initiatives supporting the efforts under various action areas. As members of the sectoral Breakthroughs, countries are committed to work together towards achieving the collective Breakthrough goal in that sector, and to participate in at least one relevant practical collaboration initiative. Countries within these groups also discuss and agree priority actions that they will jointly take, such as those announced at COP 27.

This report provides an update on the five sectors that were covered last year – power, hydrogen, road transport, steel and agriculture – in which sectoral Breakthroughs currently exist. It also adds two new sectors, cement and buildings, where countries have expressed a desire to commit to new Breakthroughs, although these are yet to be formally agreed. With these new sectors added, the Breakthrough Agenda would cover more than 60% of

global emissions. Under the IEA's NZE Scenario, these same sectors would need to deliver around 9 Gt CO_2 of annual emissions savings by 2030 versus 2022 (excluding agriculture). International collaboration will be vital in helping achieve these emission reductions, alongside strong national actions.

Figure 1.1 Greenhouse gas emissions by sector, 2019



Notes: Emissions are broken down by direct emissions in each sector. Only energy-related emissions from cement are included. Emissions from hydrogen cut across several sectors.

Source: IPCC (2022), Climate Change 2022: Mitigation of Climate Change.

The Breakthrough Agenda now covers a significant portion of the global economy.

APPROACH TO THIS REPORT

As the second annual Breakthrough Agenda Report, this is the first time we can track progress against the recommendations for international collaboration that we made the previous year. At COP 27, countries under the Breakthrough Agenda committed to joint actions in that were made in last year's report. These were put forward in the form of brief 'action plans', often with a specific timeframe and one or more nominated initiatives to co-ordinate the work within that area.

In this year's report, we assess the progress that has been made against last year's recommendations. In this we consider any progress made through collaborative international efforts involving countries, companies and civil society stakeholders, whether via the nominated initiatives or otherwise. We aim to highlight examples of good collaboration that can be strengthened through greater participation or stronger commitments, and to point out areas where the need for collective international effort is not yet being met. Factors being considered in this assessment include the change in membership of key collaborations and how representative this is of major markets and geographies; the degree of active participation in these collaborations; whether or not these collaborations are adequately resourced; if the stated ambition of these forums and initiatives is aligned with 1.5 °C trajectory; the degree of progress made against both the aims of the collaboration, as well as the recommendation made in the previous Breakthrough Agenda Report; and the extent to which roles are clearly defined within the landscape, helping avoid duplication and plug gaps. We conducted interviews with a wide range of stakeholders to inform this assessment, including government officials, industry representatives, initiative secretariats, academic experts and civil society organisations.

Taken as a whole, this allows us to provide a holistic assessment of the progress being made against our recommendations from last year's report. This assessment colours have been assigned to describe progress made towards each recommendation.

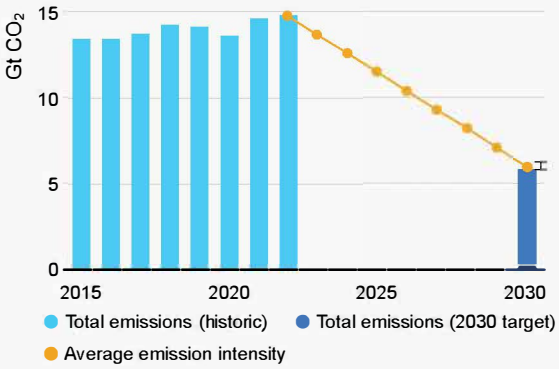
Assessment	Description
Minimal progress	Little to no progress has been made against the recommendation that was made last year, requiring urgent action from governments to increase their activity.
Modest progress	Limited progress has been made against the recommendation made last year, potentially including a limited set of governments or stakeholders, requiring greater focus in the coming years.
Good progress	Solid progress against the recommendation made last year, with broad inclusion of key countries delivering on action at a high level of ambition. Further efforts needed to get the sector on track globally.
Strong progress	The sector is now on track to deliver against this recommendation, with global action on track to meet the breakthrough statement.

The chapters on the new sectors – cement and buildings – follow a similar structure to last year's report. This includes a brief overview of progress against key outcome indicators, a summary of key actions for "how do we get there?" and an overview of the current status of international collaboration, before moving into the priorities for international collaboration and subsequent recommendations. The chapter on cross-cutting opportunities also provides an assessment of progress against the recommendations made in these areas last year, including co-ordination within each sector, financial and technical assistance, trade, research and development, and infrastructure.

POWER

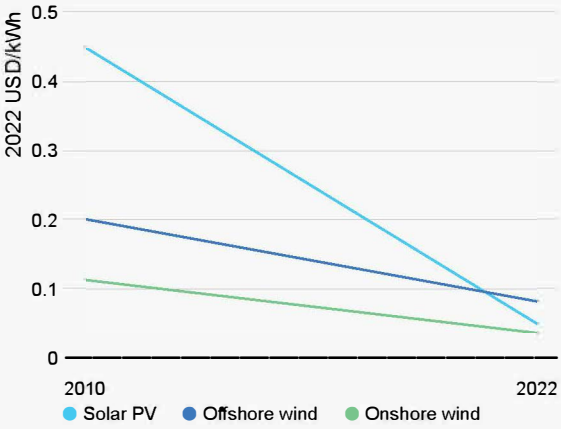
The power sector is not yet on track for net zero by mid-century, although the deployment and manufacture of key technologies have accelerated considerably in recent years. If current rates of growth in wind and solar generation continue, they are set to achieve more than half of what is required by 2030 to get on track for a net zero scenario.

Emissions[1]



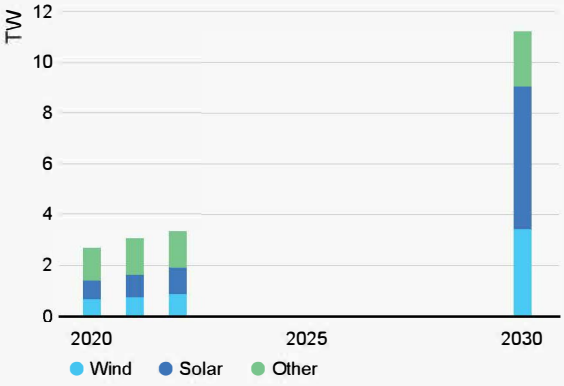
- Total power sector emissions have increased from 13.4 Gt CO_2 in 2015 to 14.8 Gt CO_2 in 2022. Emissions need to more than halve by 2030, to be in line with net zero scenarios.
- The carbon intensity of electricity is currently at around 458 g CO_2/kWh, and should achieve 99 g CO_2/kWh to align with international climate goals.

Costs[2]



- Renewable energy is less costly than fossil fuel-based electricity in a growing number of countries and makes up more than 50% of production in around 30% of countries. The average levelised cost of electricity for new projects has fallen by 89% for solar PV and 69% for onshore wind since 2010.
- The costs of storage have fallen by nearly 80% since 2015, although there are significant differences between regions.
- Recent supply chain disruptions have temporarily impacted cost reductions, and further reductions will probably be more modest in the coming year.

Deployment[3]



- Renewable share of new capacity additions has increased from 37% in 2010 to 83% in 2022.
- If solar and wind continue to expand at their current rate – doubling every 3.5 years – they will reach around 8 TW annual installed capacity by 2030. Net zero scenarios estimate that a total 11 TW renewable energy capacity is needed by 2030.
- Battery storage also needs to scale up to about 360 GW by 2030, from 25 GW in 2022.

[1] Sources: IRENA (2023) World Energy Transitions Outlook 2023 (WETO); and IEA (2021), Net Zero Emissions by 2050 Scenario.
[2] Source: IRENA (2023) Renewable Power Generation Costs in 2022.
[3] Source: IRENA (2023) World Energy Transitions Outlook 2023 (WETO).

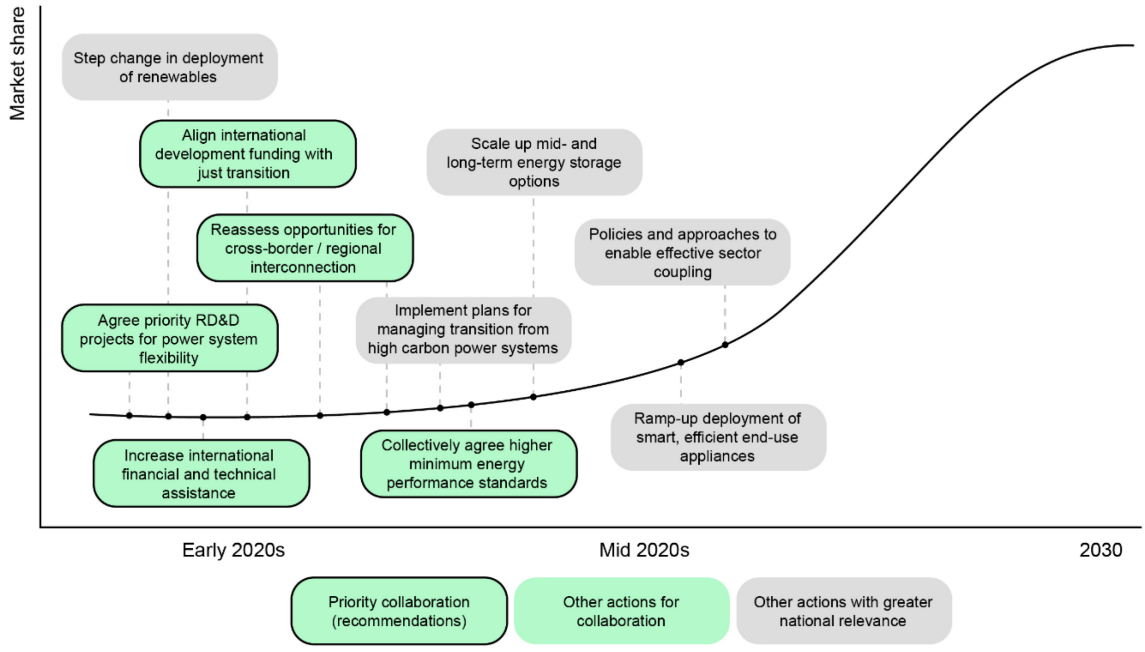
STATE OF INTERNATIONAL COLLABORATION

In last year's report, we identified international collaboration in the areas of finance, social engagement, research and innovation, infrastructure and demand management as being important to the transition in the power sector, and made recommendations on the most urgent and high-impact opportunities in need of international collaboration. In this report we assess progress against those recommendations. Our assessment is summarised in the table below, and the following sections address each area of international collaboration in turn.

Area	What progress has been made?	What more needs to be done?	2023
P2. Finance and investment	• A wave of new public and private commitments, including JETPs. • The development of innovative financial instruments improving access to finance. • Further growth in matchmaking platforms to improve access to assistance.	• Continue to increase the scale of public and private resources. • Work with MDBs to lower the cost of capital in developing countries by promoting green bonds and facilitating the use of local currencies and other mechanisms. • Improve collaboration and knowledge-sharing around successful de-risking mechanisms, including MDBs and other lenders.	Modest
P3. Social engagement	• Several support programmes announced, focused on the social aspects of the transition. • Improvements in capacity building for government officials and local industries.	• Align development funding with targeted support for economic diversification in fossil fuel dependent regions. • Develop strategies to strengthen local supply chains, using local expertise and international best practice. • Share learning among countries and support the creation of dedicated national social task forces.	Minimal
P4. Research and innovation	• Increase in participation in key public and private sector initiatives. • Countries set out priorities and plan for key demonstrations in all regions. • Strengthened collaboration and knowledge exchange among initiatives.	• Better co-ordinate efforts to research, develop and demonstrate technologies, particularly across emerging markets. • Prioritise R&D investments in key enabling technologies, such as storage, distributed energy resources and system operation. • Assess prospects for the refurbishment and repurposing of existing assets such as hydropower units and thermal power plants.	Modest

Area	What progress has been made?	What more needs to be done?	2023
P5. Infrastructure	• Countries have set clear priorities and roadmaps for regional grid initiatives. • Advanced bilateral and regional initiatives to implement or improve cross-border power exchange. • Improved knowledge exchange between regulators and other relevant actors.	• Collectively identify mechanisms to mitigate security of supply risks for cross-border infrastructure. • Explore means of reducing transaction costs and fast-tracking permitting. • Scale up manufacturing capacity to reduce current market lead time and avoid shortfalls of key materials.	Modest
	• Increased membership of efficiency and energy standards initiatives. • A modest increase in in-country assistance and technical capacity building.	• Countries to collectively agree to higher minimum energy performance standards for high energy-consuming appliances. • Improved technical and financial assistance to facilitate the application of measures.	Minimal

Figure 2.1 Critical path to 2030 for the power sector



CONTINUE IMPROVEMENTS IN THE EFFECTIVENESS OF THE DELIVERY OF TECHNICAL AND FINANCIAL ASSISTANCE FOR THE POWER SECTOR TRANSITION

OVERVIEW

Last year, we recommended that governments, working with key institutions, initiatives, and funds, should increase the scale, co-ordination, transparency and accessibility of international support in the power sector. At COP 27, countries under the Power Breakthrough agreed to support a step change in the provision of international financial and technical assistance, reinforcing the existing landscape and helping to mobilise private sector investment. The Energy Transition Council (ETC) and the Global Energy Alliance for People and Planet (GEAPP) were nominated by countries to co-ordinate support for these activities. Other active institutions include the Climate Investment Fund (CIF) and IRENA.

WHAT PROGRESS HAS BEEN MADE?

We assess that there has been modest progress made against our recommendation of last year, including via the expansion of the Just Energy Transition Partnerships (JETPs) and ongoing partnerships under the ETC.

Financial resources have been allocated to investments in renewables and the phasing out of coal plants, as well as to the enhancement of grids, distributed energy resources and energy efficiency. Collaboration has also focused on integrated energy planning, including socially just energy transitions. The CIF's Renewable Energy Integration (REI) programme has announced support to low- and middle-income countries to develop more flexible and resilient energy systems, including national grids and system operation. Investment plans for Brazil (USD 70 million, which has the potential to mobilise an additional USD 9 billion from partners), and Colombia, were approved in 2022 under the programme; plans for ten additional countries are under development.

Managed by the African Development Bank, the Sustainable Energy Fund for Africa provides catalytic finance to unlock private sector resources and has achieved over USD 500 million in donor contributions.

IRENA's Energy Transition Accelerator Financing (ETAF) Platform has received pledges from four development financial institutions, one insurance provider and one equity partner amounting to USD 1.25 billion, to scale up at least 1.5 GW of renewable energy projects by 2030. ETAF's financial resources and technical support combine with the Climate Investment Platform (CIP). Launched in 2019 as a partnership between IRENA, United Nations Development Programme (UNDP), and SE4ALL, in co-operation with the Green Climate Fund (GCF), CIP currently counts 397 registered partners, under which 70 projects

have received technical support for matchmaking between projects and financial institutions. Over 40 projects were matched, with 4 reaching financial close to date.

The ETC has facilitated access to international resources to accelerate the clean energy transition in the power sector by engaging institutions and philanthropies, and around ten donor countries have made resources available through this platform since its inception in 2021. Through its Rapid Response Facility (RRF), the ETC helped to deploy fast-acting technical assistance to 11 partner countries, based on priorities resulting from national dialogues in 2022, and there are 31 open requests across all 11 ETC partner countries.

Financial programmes have also seen increasing momentum through JETPs, with additional partnerships agreed or under discussion. JETPs are typically 3 to 5-year programmes, and the scheme was initiated with the JETP South Africa, announced in 2021. The JETP Indonesia was agreed in November 2022: it will mobilise USD 20 billion in a mix of investments and loans from private and public entities. The JETP with Viet Nam was formalised in December 2022 and will mobilise at least USD 15.5 billion, with half of this amount financed by the country members of the International Partners Group (IPG)[1] and the remainder by the Glasgow Financial Alliance for Net Zero Working Group members. Formalised in June 2023, the JETP Senegal will mobilise USD 2.7 billion through international partners and multilateral development banks (MDBs). These commitments represent a substantial increase in the funds available for countries to accelerate the energy transition, with a considerable portion of funds likely to focus on the power sector and phasing out coal.

In terms of better directing private finance, a new methodology for the use of carbon finance to create incentives for a just transition away from coal-fired thermal generation is expected to be presented at COP 28. The Coal to Clean Credit Initiative (CCCI), a partnership between the GEAPP and the Rockefeller Foundation, intends to capture revenues from selling “coal-to-clean” credits. This can then encourage the closure of coal plants and bring investments in new renewable energy projects, while supporting the transition of workers and communities.

Similarly, the African Carbon Markets Initiative aims to unlock voluntary carbon markets for financing Africa’s transition, mobilising credits valued at USD 6 billion annually, under which more than USD 1 billion would be destined to phase out coal and diesel generators in the power sector. The initiative was launched at COP 27, and was followed by publication of a 13-point action roadmap through which African nations, major credit buyers and financial institutions announced their commitments and plans to further scale up the initiative. Other innovative instruments include green bonds, which have been instrumental in raising finance in countries such as Colombia, Egypt, India and Indonesia.

[1] The IPG for Viet Nam includes Canada, Denmark, the European Union, France, Germany, Italy, Japan, Norway, the United Kingdom and the United States.

WHAT MORE NEEDS TO BE DONE?

In 2022, global investments in energy transition technologies – renewable energy, energy efficiency, electrified transport and heat, energy storage, hydrogen, and carbon capture and storage (CCS) – reached USD 1.3 trillion, an increase of 19% from the previous year. However, annual investments must triple until 2030 to meet the Paris Agreement goals.

International assistance can play a role in this by supporting the design and implementation of policies that mobilise and reallocate private investment, and by providing concessional finance. So far, demand for funding programmes has been considerably higher than available resources[2]. An additional limitation of current international financial assistance is that it has typically concentrated on less risky investments such as renewables and energy efficiency. A clearer focus on other higher-risk but systemically important technologies including energy storage (both short and long-term duration), distributed energy resources and sector coupling is needed, along with new business models.

Countries should work together, particularly through MDBs, to mobilise additional resources for the power sector transition. In particular, this includes collectively identifying funds that can enlarge their liquidity facilities and increase credit availability, leveraging MDBs' track records in managing risks. Furthermore, grants to support early-stage studies can better identify opportunities, increase transparency of the potential outcomes, and upskill project partners, reducing risk from the start.

Governments and development finance institutions can play a significant role in de-risking private projects and thus leveraging private finance. That includes securing revenues and hedging against key uncertainties such as currency and infrastructure risks (e.g. lack of transmission lines).[3] As a result, reducing risks can create a more positive environment for investment, helping to lower costs of capital. Countries can also facilitate blended finance strategies. Exchange of knowledge and experiences is essential. For instance, the World Bank's sustainable renewables risk mitigation initiative has gathered knowledge on enhancing private sector investments through de-risking and could support other actors.

In addition, public resources and policies should both reform and tailor the means of lending to different contexts and needs, including increasing willingness to riskier environments. As argued by proponents of the Bridgetown Initiative, it is critical that financial aid does not create an additional burden for countries. More attention should be paid to policies that give governments more flexibility (fiscal space) in their spending choices, including the use of local currency in settling debt.

In summary, demand for funding programmes has been considerably higher than available resources[4]. Therefore, an increase in public funding needs to be delivered, building on

[3] Agreements that ensure revenues at pre-defined price points such as Power Purchase Agreements (PPAs) or contracts-for-difference (CfDs) contribute to reducing risks. Alternatively, securing liquidity facilities can ensure continued cash flows from off-takers without burdening countries by providing short-term liquidity, covering risks and improving the project's creditworthiness.

existing programmes to strengthen the collective impact at the speed and scale required. This could be enabled through platforms such as the CIF, ETC, and IRENA's ETAF, which can connect technical partners with developing countries. MDBs and other funding institutions could deliver joint progress reports, setting out total resources committed and disbursed, successful case studies and key focus areas for future projects. This message was echoed in the Brasilia Declaration on the Future of the Climate Investment Funds (CIF) in 2023, where countries envisaged major climate and environmental funds like CIF, the GCF and the Global Environment Facility joining forces. Initiatives should also engage national development banks and other specific vehicles, including UN-linked funds such as the GCF. Lastly, funding must be secured to support initiatives' co-ordination functions, which are often missed out during programme discussions.

RECOMMENDATION P2 HAS BEEN UPDATED AS FOLLOWS:

Donor governments, working with key institutions and funds, should ensure that international support is available at better terms, including grants at early investment stages for higher-risk projects. That includes creating de-risking mechanisms, tailored to the country's respective contexts, and technical assistance for regulatory reforms, both of which can help to mobilise private sector investments. Overall provision of resources should be significantly increased, particularly for technologies that have not achieved commercial maturity, such as energy storage.

DRASTICALLY IMPROVE TARGETED SUPPORT FOR LOCAL JOBS, SKILLS AND INVESTMENT IN FOSSIL FUEL DEPENDENT COMMUNITIES

OVERVIEW

Last year, we recommended that countries should work together with MDBs to better align development financing with targeted support for local jobs, skills and investment, particularly in fossil fuel dependent regions. At COP 27, countries under the Power Breakthrough agreed to scale up support for just transitions by developing common plans to accelerate the alignment of cross-cutting development finance lending programmes by COP 28. Key initiatives and organisations to take this forward include the ETC, the International Labour Organization (ILO) and CIF – in particular, the Accelerating Coal Transitions investment programme. Other relevant forums and agreements include IRENA's Collaborative Framework for Just and Inclusive Energy Transitions, IEA's Global Commission on People-Centred Clean Energy Transitions, and the Just Transition

Declaration, which builds on ILO's Guidelines for a Just Transition. The Africa Just and Affordable Energy Transition Initiative (AJAETI) is also relevant in its role to empower local communities and equitable approaches and promote entrepreneurial innovation.

WHAT PROGRESS HAS BEEN MADE?

We assess that there has been minimal progress made against our recommendation of last year. Although there are several initiatives in place to address the needs of specific countries for the just transition, there is limited visibility into the extent of co-operation between developed governments and MDBs in aligning development funding with targeted support for the just transition.

The JETPs have been set up in selected countries to provide international support to address the social consequences of the energy transition. They intend to promote training and job creation for affected workers, while encouraging economic diversification and innovation. For example, South Africa's JETP national plan, released in November 2022, sets out activities to develop sectors and strategies for capacity building. However, economic diversification and innovation and skills development make up only 0.4% of the total amount planned. Indonesia's JETP aims to support development of a local renewables industry by mobilising investments in local manufacturing capacity and energy efficiency. It will also focus on the most vulnerable groups, such as coal industry employees.

In 2022, ILO evaluated the impact of the coal phase-out on jobs in Indonesia, the Philippines, and Viet Nam, and proposed a framework for co-operation among actors. In the past year, the ILO has also evaluated job conditions for Brazil, Indonesia, Mauritius and Türkiye under the Climate Actions for Jobs (CA4J) initiative. Other relevant learning resources include the World Bank's recommendations on transitioning jobs, the UNDP's assessment for China, and NewClimate Institute's assessment for China and Europe.

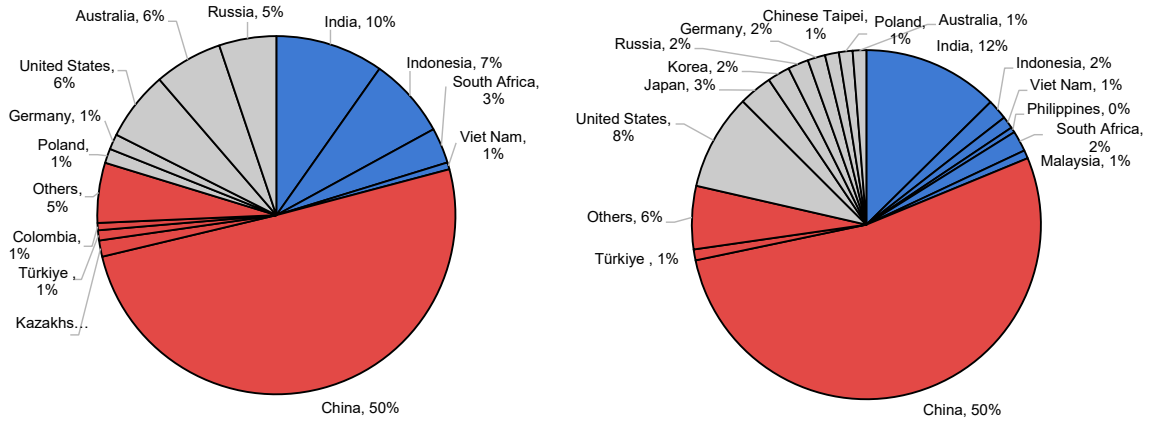
Restructuring local economies must capitalise on regional strengths and opportunities in the global market. Launched in January 2023, the Renewable Energy Manufacturing Initiative (REMI) has developed an implementation roadmap for the next five to eight years, which aims to support African countries in scaling up their manufacturing capabilities for power generation technologies, with assistance from a number of entities.[5] The initiative has undertaken an inception study that includes estimates for the investment needs for developing local assembly of solar modules and batteries across ten African countries, and potential costs of the final product. REMI now plans to develop pilot projects and explore synergy opportunities with a larger group of non-African countries, and particularly with China, the world's largest manufacturer of clean energy technologies. If successful, there is potential for the work of REMI to be replicated in countries throughout Latin America and Asia.

[5] The REMI is a collaboration of Sustainable Energy for All, the African Climate Foundation, Bloomberg Philanthropies, ClimateWorks Foundation, and the Chinese Renewable Energy Industry Association.

WHAT MORE NEEDS TO BE DONE?

Countries included as members in the initiatives mentioned above cover roughly 17-20% of global coal production and coal-based power generation (see Figure 2.2). While a promising start, there is significant potential for expansion of activity into more coal-using regions. In addition to these individual initiatives, it is imperative to integrate the principles of just transition by setting clearer strategies for the creation of jobs and economic diversification activities into the broader spectrum of financial development assistance offered by the MDBs. Further efforts need to be made to strengthen the co-operation between donor governments and MDBs to effectively align development funding with support for the just transition. A focus on both developing and emerging economies is necessary, given the scale of the challenge. The impacts of the transition will differ depending on a country's economy and labour market structure, so strategies must be both targeted and holistic.

Figure 2.2 Share of coal production (left) and coal-based power generation (right) by country, 2022



Note: Blue denotes a country that is a recipient of just transition support, red denotes countries that are not currently addressed, and grey denotes developed countries.

Source: Reprinted from Ember (2023), Yearly electricity data (database), (accessed September 2023); The Shift Data Portal (2023), Explore World energy and climate data (database), (accessed September 2023).

Just transition initiatives cover a large share of coal producing countries, although the impact of programmes remains to be seen.

Central to the JETP announcements are the aims of restructuring local economies and creating jobs, which overall involve a wide range of stakeholders. When establishing such partnerships, developing countries and JETP's IPG members should increase the focus on local supply chains, including small and medium enterprises. These are often sensitive to market disruptions and are often under-resourced relative to larger companies. This should also include activities to create new opportunities for the local workforce. Countries should

therefore define clear expectations and roadmaps for labour, education infrastructure and new businesses early in the process, even before setting financial resources.

During these processes, countries involved in establishing these programmes should proactively consult civil society organisations to support the creation of centres of expertise and provide feedback on the policies being proposed. Universities and graduates can benefit from and contribute to the establishment of new clean technology sectors.

Countries may not have reliable data on labour and skills to develop strategies for the transition and so countries should work together to fund and develop pre-implementation studies that can provide a more accurate overview of the current and future labour impacts. ILO can be instrumental in supporting JETPs with this task. The CIF's Just Transition Initiative has produced research and carried out knowledge-sharing activities, including creating a resource library to locate key research material and policy guidance. It also created a Just Transition Planning Toolbox that provides planning steps, tools, and case studies that guide policy makers through delivering a just transition in a systematic way.

This can include promoting dialogue between countries to exchange lessons learned, which ultimately can help inform strategies for the future workforce and economic resilience. Governments may consider creating specific just transition task forces to engage with other countries going through the same process, and connect local action with international experience exchange. This would include supporting a social dialogue with workers, employers and governments to help understand the local context. An ongoing example is the United States-India partnership on just transition from coal, which will explore collaboration and strategies, including sub-national exchange between coal-rich US and Indian regions to share best practices.

In summary, there are an increasing number of activities to address the socio-economic impacts of the energy transition. However, activities are still at an early stage and large-scale results in terms of successful regional transitions are yet to be observed. Accelerating learning between those projects that are working well, and using this to better target resources to a greater number of fossil fuel dependant regions, will be vital to guarantee a just transition in the power sector.

RECOMMENDATION P3 HAS BEEN RESTATED AS FOLLOWS:

Donor governments and MDBs should work together to more strongly align development funding with targeted support for local jobs, skills and investment, for the repurposing of fossil fuel assets, economic diversification, and for environmental restoration, in fossil fuel dependent regions and communities. Civil society, governments and industry should contribute to creating international centres of expertise on the just transition, within existing institutions.

ACCELERATE THE DEPLOYMENT OF PRIORITY PROJECTS SHOWCASING NOVEL TECHNOLOGIES AND SOLUTIONS ACROSS MULTIPLE REGIONS

OVERVIEW

Last year, we recommended that countries should agree on strategic priority projects to demonstrate state-of-the-art solutions that are fundamental to the transition in the power sector. At COP 27, countries under the Power Breakthrough agreed to collaborate to identify new system-wide innovations and large-scale demonstration projects that are currently under-resourced, in order to accelerate delivery and share lessons. Countries nominated the Mission Innovation Green Powered Future Mission (GPFM), the Global Power System Transformation Consortium (G-PST), and Breakthrough Energy to take this forward. These initiatives have as members countries accounting for more than 60% of global electricity generation, in addition to private companies and intergovernmental organisations.

WHAT PROGRESS HAS BEEN MADE?

We assess that there has been modest progress against our recommendation made last year, with some notable steps taken by countries under the nominated initiatives.

Setting priorities for the short- and medium-term is essential to assist policy-making. GPFM made strides with piloting crucial solutions for power sector decarbonisation in 2022, following on from the innovation priority-setting exercise in its 2021 Roadmap. The 2022-24 GPFM Action Plan whittled the 2021 list of 100 priorities down to the 50 most urgent short-term priorities, of which 20 will be addressed through a research programme to be launched in September 2023.[6] IRENA also undertook a similar exercise in 2023 through its Innovation Landscape for Smart Electrification. This provides an innovation toolbox that includes 100 innovations (35 for power to mobility, 35 for power to heating and cooling, and 30 for power to hydrogen) to support strategies for the smart electrification of end-use sectors, broken down by the stage of development.

Innovative solutions need to be tested in controlled settings before being scaled up, allowing for refinement and ensuring they are fit-for-purpose, thereby reducing risk and saving time and resources in the long run. The GPFM plans to start on five large demonstration projects by 2024, aimed at systems with up to 80% share of variable renewable energies (VRE). This will cover different technical, regulatory and market

[6] Some of the priorities defined by GPFM to be addressed by the 2023 programme are: 1) high efficiency PV cells and modules; 2) recycling of PV; 3) floating off-shore wind turbines; 4) system reliability and stability; 5) storage technologies; 6) grid supporting with inverter-based tech; 7) VRE flexibility; 8) enhanced transmission system operator-distribution system operator (TSO-DSO) co-ordination for flex markets; 9) DSO flexibility management; 10) utility-scale storage for system service provision; 11) unlocking flexibility from distributed energy resources (DER)/buildings; 12) demand response, electric vehicles and grid impact; and 13) markets for the provision of ancillary services by VRE and storage flexibility provision.

frameworks across five continents. The first demonstration project will test the integration of large-scale offshore wind and required transmission in such an environment in Asia. The second intends to test distinct storage and sector coupling interface technologies and innovative market and regulatory frameworks in Europe. Task forces on each continent will monitor progress and encourage knowledge sharing among each of these pilots through a toolbox and regular workshops.

In 2022, the Energy Sector Management Assistance Program (ESMAP)'s Energy Storage Partnership (ESP) focused on developing its Global Network of Energy Storage Testbeds initiative with India, Morocco and South Africa in order to accelerate the commercial deployment of pre- and early-market technologies. ESP has also carried out assessments and case studies on various technologies and business models in different settings around the world.

In step with technological change, there have been profound changes to the modalities through which power assets connect and behave, and how power systems are operated. In response, G-PST[7] has prioritised activities to develop new standards for deploying relevant technologies like storage, grid forming inverters and distributed energy resources. G-PST has also provided countries with technical support to improve system operation, building on best practices of TSOs in countries with significant shares of variable renewables. Recent activities have included stakeholder meetings to support better integration of VREs in Indonesia and in Peru. TSOs from Colombia, India, South Africa and Viet Nam were supported with various technical assistance efforts.

At the national level, the Clean Energy Ministerial (CEM)'s 21st Century Power Partnership (21CPP)[8] supports policy and regulation via direct technical assistance and capacity building. In July 2023 at the CEM14 meeting, a country cohort of Australia, Chile, the European Union, India and the United Kingdom presented ongoing national Action Plans on topics such as planning, project development and operation, which can bring insights to other regions. Quarterly peer-learning workshops will address technical challenges related to countries' Action Plan goals, with cohorts expected to grow annually. Plans are underway to announce a second cohort for CEM15 in 2024.

Other examples of progress include regional workshops organised by Renewables in Latin America and the Caribbean in 2022 to showcase regulatory and institutional best practices. CIF launched the REI Learning Platform in July 2023 to strengthen national capacities and readiness. From a demand-side perspective, Integrate to Zero has provided support and gathered knowledge on integrating distributed resources to enhance system flexibility while creating value for consumers.

[7] The G-PST strategic priorities are based on five key areas, namely: 1) operators peer learning; 2) technical support for operational solutions; 3) workforce training; 4) technology standards and certification; and 5) open tools and data.
[8] Co-led by Brazil, India and the United States, with an advisory group from the private sector and non-profit organisations.

WHAT MORE NEEDS TO BE DONE?

The activities being undertaken by countries and supporting organisations broadly align with our recommendation from last year, with some promising results being delivered in major developing economies. However, countries will need to allocate sufficient levels of funding to ensure that these projects come to fruition early enough to inform policy reforms that are critical to the pace of the transition.

Governments should also explore how to best make use of existing generation assets through retrofitting or repurposing, which can reduce the costs of the transition. Though probably the most mature renewable technology, existing hydropower has typically been in operation for 30-50 years, which means its ageing fleet requires modernisation to meet ever-evolving power system needs. Enhanced digitalisation will be key to achieving the necessary adjustments to plant design, operation and maintenance. IRENA's Collaborative Framework on Hydropower has facilitated knowledge sharing between countries, but additional international efforts are needed to explore retrofitting options, to help map eligible candidates, and to raise awareness. This can build on the work done by the International Hydropower Association, comprising members from the private sector across 120 countries.

Similarly, further work is required to explore the potential for coal and gas-fired plants to be repurposed to provide services such as inertia and system strength. Repurposing has the potential to allow faster implementation at a lower cost compared to building new facilities, and additional research is needed to determine conversion options, and the conditions under which this route could be feasible. Plants may also be converted for sustainable biomass, biogas, waste, geothermal or nuclear, informed by CIF's Repurposing for Advancing Coal Transition Tool that aims to support decision-making.

RECOMMENDATION P4 HAS BEEN UPDATED AS FOLLOWS:

> Governments should work through relevant initiatives to accelerate the identification and implementation of suitable demonstration projects, resource them appropriately, and ensure high-quality knowledge-sharing structures are put in place. To facilitate knowledge sharing among a wider set of countries and stakeholders, close collaboration with regional research and innovation networks will be required.

REASSESS OPPORTUNITIES FOR CROSS-BORDER ELECTRICITY TRADE, ACCELERATED BY ENHANCED TECHNICAL SUPPORT

OVERVIEW

Last year, we recommended that countries should work together to reassess the opportunities for cross-border and regional power interconnection, to identify top regional priorities for interconnection, and to replicate successful approaches to technical agreements. At COP 27, countries under the Power Breakthrough agreed to collaborate to develop and implement effective approaches and standardised tools to support local and cross-regional grid system flexibility. Countries nominated the Green Grids Initiative (GGI) and the United Nations Economic and Social Commission for Asia and the Pacific to accelerate activity in this area, alongside G-PST and CEM initiatives, the International Smart Grid Action Network (ISGAN) and the 21st Century Power Partnership (21CPP).

WHAT PROGRESS HAS BEEN MADE?

We assess that there has been modest progress against our recommendation made last year, with some notable steps taken among countries in terms of setting joint priorities and establishing regional frameworks for electricity exchange.

Countries have made progress towards defining priorities for cross-border interconnection, and regional initiatives such as the African Continental Masterplan, The Association of Southeast Asian Nations (ASEAN) Power Grid, and enhancements on the Central America Corridor have advanced.

Members of the GGI, comprising state and non-state actors, met in March 2023 to build consensus on a set of priority projects. These include the Principles and Protocols for Interconnectors, which uses case studies and best practices from Europe, including experience from the North Sea, to provide actionable advice for policy makers on the development of interconnectors. The principles are initially aimed at the Asia-Pacific region but should be universally applicable. GGI is also developing an Electricity Transition Playbook, which was trialled in 2023 with support from the Climate Compatible Growth initiative, with the aim of formally launching at COP 28.

Agreeing on milestones for deploying specific cross-border grids and markets has the potential to greatly reduce lead times for future interconnection projects, given their complexity. The Economic and Social Commission for Asia and the Pacific (ESCAP), through its expert working group on energy connectivity, has conducted two meetings since September 2022 to advance the Regional Road Map on Power System Connectivity and finalise the Green Power Corridor Framework, which was launched in 2021. This builds on nine strategic priorities, with proposals for key milestones, timeframes and responsible

entities.[9] ESCAP has also engaged with the ASEAN Power Grid (APG) to assess North-East Asia Interconnection, and enhance power trade in South Asia. It also developed a Green Power Corridor Roadmap for Northeast Asia, which will be published in November 2023. Additionally, ESCAP recently launched a project in collaboration with the Economic Cooperation Organization to study the feasibility of developing a regional electricity market.

Also in Asia, in 2022 the Greater Mekong Subregion collaboration released guidelines on how to overcome regulatory challenges and political concerns to build a fully synchronised network between Cambodia, Lao People's Democratic Republic,[10] Myanmar, Thailand and Viet Nam, along with southern provinces of China. Further progress across that region includes Singapore's adherence to the existing Laos-Thailand-Malaysia Power Integration Project (LTM-PIP) framework in 2022.[11] This process can bring technical and regulatory insights to other ongoing discussions in the region and is a step towards the APG.

Program Infrastructure Development for Africa (PIDA), a joint initiative of the African Union Commission, the African Union Development Agency - New Partnership for Africa's Development (AUDA-NEPAD), aims at integrating the regional infrastructure in four sectors, one of which is energy. This included around 20 regional infrastructure projects (power generation and transmission) to be completed by 2030. In parallel, the development of the Continental Power System Masterplan (CMP), led by AUDA-NEPAD, is being concluded in 2023. CMP has been developed by experts of AUDA-NEPAD and the five African power pools, with modelling support from IRENA and the IAEA, and validated through consultative processes with African institutions and development partners supporting this effort. CMP is to serve as a blueprint for the African Single Electricity Market (AfSEM), a flagship initiative of the African Union aiming at creating a unified market framework across the continent by 2040. Five strategic working documents have been produced in 2022.

Learning through collaboration is fundamental in areas such as regulation and market conditions. The Regulatory Energy Transition Accelerator (RETA) aims to support this through a growing network of 44 energy regulators and regulatory associations from several countries, working in partnership with organisations such as the IEA, IRENA and the World Bank. A RETA workshop on regional interconnection that took place in 2023 brought together participants from 18 countries to better inform its technical support activities. The top challenges identified by participants included a lack of consensus between jurisdictions; challenges with agreeing on institutional arrangements, market modalities and network rules; and a lack of co-ordination in planning and investment.

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[9] UNESCAP's Power Connectivity Strategies are: 1) Build trust and political consensus for cross-border electricity trade; 2) Develop a regional cross-border electricity grid master plan; 3) Develop and implement intergovernmental agreements on energy co-operation and interconnection; 4) co-ordinate, harmonise and institutionalise policy and regulatory frameworks; 5) Move towards multilateral power trade and create competitive markets for cross-border electricity; 6) co-ordinate cross-border transmission planning and system operation; 7) Mobilise investment in cross-border grid and generation infrastructure; 8) Build capacities and share information, data, lessons learned and best practices; 9) Ensure the coherence of energy connectivity initiatives and the Sustainable Development Goals.

[10] Hereafter Laos.

[11] The LTMS-PIP (Lao PDR-Thailand-Malaysia-Singapore Power Integration Project) enables imports from Lao PDR to Malaysia and Singapore, using Thailand's existing network.

WHAT MORE NEEDS TO BE DONE?

To accelerate the effective deployment of cross-border electricity trade, countries should work together to ensure that important technical and non-technical barriers are addressed. These include institutional challenges to harmonising standards and procedures, which add to the complexity of agreeing cross-border electricity trade. Countries typically have different power market arrangements, pre-existing agreements that need to be fulfilled, and varying policies across jurisdictions, all of which must be tailored to comply with a common regional approach.

Countries looking to engage in cross-border electricity trade typically have to agree on frameworks for disclosing important technical and economic parameters of national power market design and physical assets, and addressing these points from the beginning can accelerate the negotiation of trade agreements. Successful experiences such as the European Single Market and the Southern African Power Pool, which gather several countries under the same framework in pursuit of a common goal, can provide examples of where collaboration has provided a foundation for discussing pre-market standards such as capacity obligations and the disclosure of costs, the implementation of platforms required for spot and forward energy markets, and balancing mechanisms.

Other barriers to accelerating the development of regional electricity markets include a prioritisation of national over regional projects, and uncertainties in the security of cross-border electricity supply. It is therefore essential for countries to agree clear rules and identify secure mechanisms that can de-risk potential supply disruptions and avoid unjustified supply enforcements, using market arrangements that can appropriately compensate both parties. Countries should also agree time-bound milestones for deploying regional priority cross-border interconnection projects, to focus collective attention on the pace of progress.

More recently, the process of building transmission lines has become even more challenging with a severe shortage of equipment. Several transmission projects across the globe have been delayed due to limited availability of cables, converters and other grid equipment in a market supplied by few companies. Constraints on critical materials like copper and aluminium have added a layer of complexity, as has a shortage of skilled workers, particularly in developing countries. Renewables and storage projects have experienced long queues to connect onto the grid, a result of insufficient grid capacity and slow institutional processes. Government engagement with industry is needed to identify priorities and provide incentives to help enhance the manufacturing capacity to further reduce market lead times for key components. Countries can also facilitate long-term contracts for the supply of key materials, which are typically internationally traded, so as to avoid the industry falling short on them and other supplies. At the same time, countries can exchange best practices on how to speed up permitting processes for connecting solar, wind and storage onto national grids.

RECOMMENDATION P5 HAS BEEN RESTATED AS FOLLOWS:

Governments should work together to reassess the opportunities for cross-border and regional power interconnection and smart grids to support the transition to clean power systems, including opportunities that have been previously considered but not taken forward, given the improving technology, falling costs, and increasing need for system flexibility. Countries and investors should support international efforts to identify top regional priorities for interconnection, and to replicate successful approaches to technical agreements.

COLLECTIVELY AGREE HIGHER MINIMUM ENERGY PERFORMANCE STANDARDS FOR MAJOR ELECTRICITY-CONSUMING APPLIANCES

OVERVIEW

Last year, we recommended that countries should collectively agree higher minimum energy performance standards for high energy-consuming appliances. At COP 27, under the Power Breakthrough, countries agreed on action to promote energy efficiency standards for products by supporting improved technical and administrative assistance. Countries nominated the CEM Super-Efficient Equipment and Appliance Deployment (SEAD) Initiative and Climate Group's EP100 to lead this work, with support from Mission Efficiency (formerly the Three Per Cent Club) and Climate Group's EP100.

WHAT PROGRESS HAS BEEN MADE?

We assess that there has been minimal progress made against our recommendation for countries to agree higher minimum energy performance standards, but there has been modest progress in increasing technical assistance for countries to develop such standards.

Since 2022, SEAD's membership has grown to 24 countries, with the addition of Panama and Türkiye, and additional member organisations, including The European Bank for Reconstruction and Development (EBRD) and EP100. Over the same period, SEAD led two major training events in Latin America and sub-Saharan Africa, delivered more than ten bilateral policy exchanges with governments and developed an online training course on Appliance Energy Efficiency Policy. In 2023, the initiative aims to use in-country assistance to support the delivery of the Product Efficiency Call to Action, which now has 14 countries as signatories.

Mission Efficiency currently has 16 member countries and works with over 60 technical and finance partners to deliver energy efficiency infrastructure and project investments, making a clear case for energy efficiency alongside the development agenda. It also currently

works with four major International Financial Institutions (IFIs) to support funding for these projects, including GEF, EBRD, GCF and the Inter-American Development Bank.

EP100 is a private sector initiative, through which members sign up to at least one of three commitments: 1) double energy productivity; 2) implement an energy management system; or 3) own, occupy or develop net zero carbon buildings. EP100 currently has over 120 members, although with a strong focus in Europe.

WHAT MORE NEEDS TO BE DONE?

As a result of these efforts, we have seen a strong improvement in technical assistance, particularly in those regions that have the greatest potential for electricity demand growth. This is yet to translate into a significant number of new countries taking up higher minimum energy performance standards, suggesting efforts need to be further accelerated and scaled up. This should include: 1) political dialogue on the product efficiency standards consistent with international climate change goals; 2) jointly increasing the effectiveness of energy efficiency policies for appliance equipment across multiple markets; and 3) connecting government officials to learn from their peers.

There remains an unexploited opportunity for countries to accelerate progress by agreeing higher minimum energy performance standards for high energy-consuming appliances. In many cases, appliances are traded internationally, and manufactured by companies that sell to multiple countries. A relatively small number of countries can have a disproportionally large impact on the global market. For example, in 2021 nine countries (the G7 plus the Netherlands and Spain) accounted for over half of global imports of refrigerators, and four countries made up over half of global exports. Co-ordination on standards by these countries could decisively shift the global market towards more efficient products. Given that strong energy efficiency standards have historically been shown to accelerate innovation and cost reduction, this would be to the benefit of all countries.

RECOMMENDATION P6 HAS BEEN RESTATED AS FOLLOWS:

Countries, in consultation with industry, should collectively agree to higher minimum energy performance standards for high energy-consuming appliances, supported by awareness campaigns and incentives, such as energy efficiency retrofit programmes. Improved technical assistance should facilitate the implementation of effective standards in developing countries.

RECOMMENDED REPORTS

We recommend the following reports for more detailed descriptions of the technologies for power sector decarbonisation and of the actions that countries and businesses can take individually.

Net Zero by 2050 (IEA, 2021).

Making Clean Electrification Possible (ETC, 2021).

World Energy Outlook 2022 (IEA, 2022).

Renewable Power Generation Costs in 2021 (IRENA, 2022).

RE-organising Power Systems for the Transition (IRENA, 2022).

Global landscape of renewable energy finance (IRENA & CPI, 2023).

World Energy Transitions Outlook 2023 (IRENA, 2023).

Scaling Up Private Finance for Clean Energy in Emerging and Developing Economies (IEA, 2023)

The cost of financing for renewable power (IRENA, 2023).

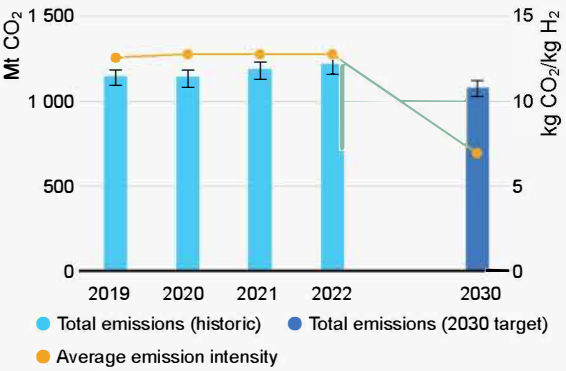
Low-cost finance for the energy transition (IRENA, 2023).

Financing Clean Energy in Africa (IEA, 2023)

HYDROGEN

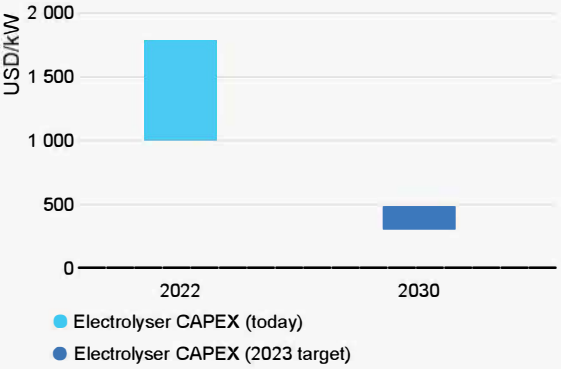
The deployment of renewable and low-carbon hydrogen is significantly below where it needs to be under a net zero scenario, despite continuing to receive significant interest. More than 1000 hydrogen plants are planned, although greater certainty of policy support and demand is required to move plans and announcements into real projects.

Emissions[1]



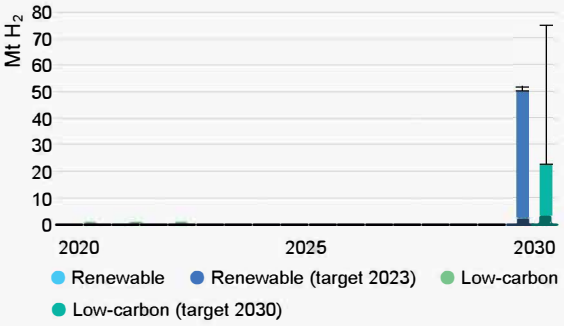
- There has been no significant reduction in total emissions from hydrogen production, due to the slow uptake of low-carbon and renewable hydrogen.
- Average emissions intensity of hydrogen production remains high as there have been no significant changes in the production mix.
- Emissions intensity needs to fall by nearly 50% by 2030, resulting in a 10% reduction in total emissions from hydrogen production.

Costs[2]



- Renewable and low-carbon hydrogen remains more expensive than hydrogen from unabated fossil fuels.
- Alongside renewable electricity cost and availability, electrolyser capital cost is an important part of the cost of renewable hydrogen.
- Electrolyser capital cost is expected to decrease through accelerated innovation, scale-up and improved manufacturing techniques, although recent increases in material costs risk slowing down these cost declines.

Deployment[3]



- Renewable and low-carbon hydrogen has continued to grow since 2020 but remains below 1% of global hydrogen production.
- Total global hydrogen production stood at 95 Mt in 2022.
- Low-carbon and renewable hydrogen production reached 0.7 Mt in 2022, compared with 70-125 Mt/yr required by 2030.

[1] Global CO2 emissions and average emission intensity of hydrogen production, IEA. Error bars reflect the variability of emissions depending on the allocation method for the production of hydrogen as a by-product in the petrochemical industry.

[2] Electrolyser capital costs, IEA and IRENA. The 2030 target refers to the projected cost in the IEA's Net Zero Emissions by 2050 Scenario (NZE Scenario) and IRENA's 1.5 °C Scenario.

[3] Production of low-carbon and renewable hydrogen and share of total hydrogen production, IEA and IRENA. Dashed areas represent variability between IEA's Net Zero Emissions by 2050 Scenario (NZE Scenario) and IRENA's 1.5 °C Scenario.

STATE OF INTERNATIONAL COLLABORATION

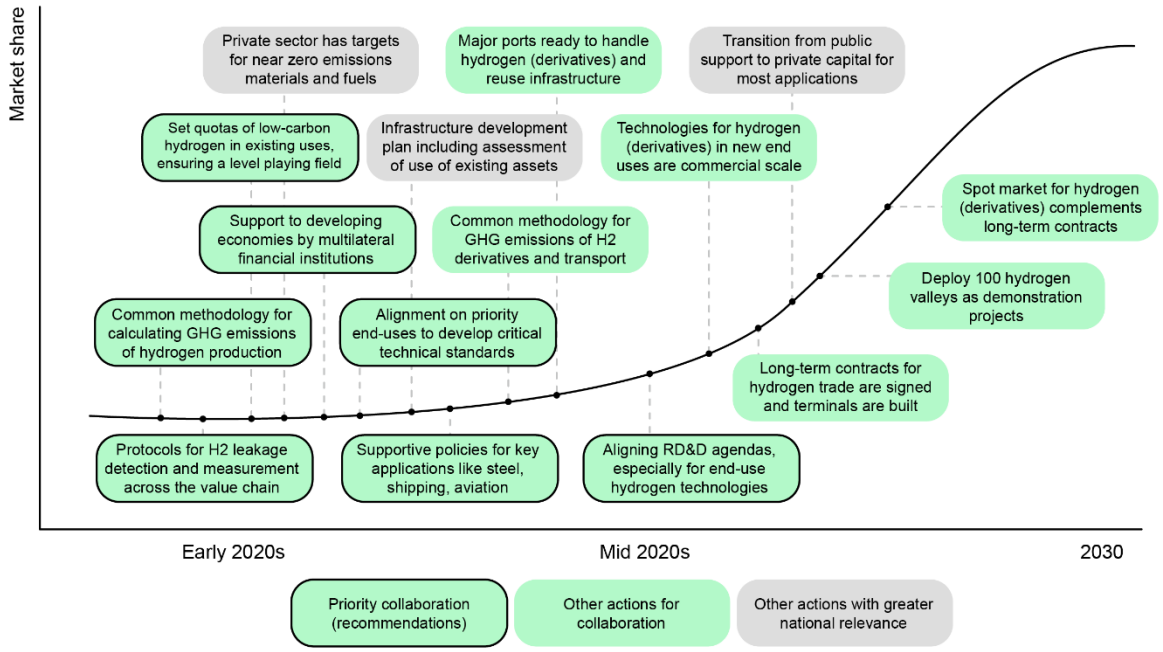
In last year's report, we identified international collaboration in the areas of standards and certification, demand creation, technology demonstration and finance as being important for scaling up the production and use of low-carbon and renewable hydrogen[1], and made recommendations on the most urgent and high-impact opportunities in need of international collaboration in each of those areas. In this report we assess progress against those recommendations. Our assessment is summarised in the table below, and the following sections address each area of international collaboration in turn.

Area	What progress has been made?	What more needs to be done?	2023
H1. Standards and certification	• IPHE leading major efforts on methodologies, in partnership with ISO, and increasingly co-ordinating the wider landscape. • IEA Hydrogen TCP has set a task on certification harmonisation. • Other assessments or relevant work from IRENA and RMI, the European Clean Hydrogen Alliance and the Hydrogen Council.	• Prepare a well-articulated plan that defines resource needs for the development of a comprehensive portfolio of standards. • Provide appropriate resources to undertake the relevant work on standards development. • Governments to work through existing forums to ensure methodologies used to define regulatory frameworks are interoperable.	Modest
H2. Demand creation	• Notable individual efforts from countries, albeit lacking international coordination on near-term commitments and policies. • The IRENA Collaborative Framework on green hydrogen has established a workstream on understanding how to co-ordinate demand and supply globally.	• Increase the strength of the demand signal by moving from commitments and pledges to contracts and policies. • Improve co-ordination of efforts by more countries and companies working through joint initiatives.	Minimal
H3. Research and innovation	• Commitment to establish a conceptual framework to exchange best practices by COP 28. • The Hydrogen Valley Platform had identified 83 projects from 33 countries by July 2023.	• Ensure new projects are focused in priority sectors and increase geographical diversity of demonstration projects. • Increase efforts to establish proactive knowledge-sharing platforms and processes between lead projects.	Minimal

[1] While this report does not define a specific carbon intensity limit for low-carbon and renewable hydrogen, both of these production routes will need to achieve verifiable low-carbon intensities that trend towards near zero by 2030. This implies that fossil-based hydrogen production must operate with high carbon capture rates applied to all streams containing CO2, and that the captured carbon must be permanently stored underground to prevent its release into the atmosphere. Additionally, it is critical that methane leakage is reduced to near zero, if not completely avoided. Rigorous measurement, reporting and verification of emissions will be necessary.

Area	What progress has been made?	What more needs to be done?	2023
H4. Finance and investment	• UNIDO, World Bank and IRENA mapping currently available assistance and financing best practice, to support an improved offer. • The Hydrogen for Development Partnership was launched by the World Bank, to help catalyse funding for projects in developing countries through providing improved in-country support.	• Governments to work with IFIs to identify projects that are being delayed by high costs of capital and other obstacles to investment, then identify best practices to support targeted and tailored technical assistance for policy design.	Modest

Figure 3.1 Critical path to 2030 for hydrogen



ACCELERATING THE DEVELOPMENT OF COMMON STANDARDS FOR HYDROGEN EMISSIONS, SAFETY AND OPERATIONS WITH INCREASED GOVERNMENT SUPPORT

OVERVIEW

Last year, we recommended that countries and companies should agree a comprehensive portfolio of international standards and associated certification schemes, and should support their development with appropriate resources. At COP 27, countries under the Hydrogen Breakthrough agreed to accelerate and expand a co-ordinated programme of work to develop these standards and associated certification schemes, committing to fully resource this programme by COP 28 and to report progress annually at subsequent COPs.

The International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) was nominated to co-ordinate this work, with support from IEA's Hydrogen Technology Collaboration Programme (TCP) and IRENA's Collaborative Framework on Green Hydrogen.

Increasing the use of hydrogen[2] to support decarbonisation will require the development and adoption of robust and globally harmonised standards relating not only to emissions, but also to overall sustainability (including water and land use), safety, and operations in new applications and technologies that are not yet part of the energy system. International collaboration will be a vital enabler, ensuring that hydrogen (and its derivatives) can be safely used and effectively traded across borders, and minimising the administrative burden for companies.

WHAT PROGRESS HAS BEEN MADE?

We assess that modest progress has been made against our recommendation on standards and certification last year, with notable efforts by countries via IPHE and ISO.

In support of these efforts, in 2022 the IPHE member countries, through the Hydrogen Production Analysis Task Force, developed methodologies for evaluating emissions from different hydrogen production methods and carriers. The final version of the working paper is expected to be published in the third quarter of 2023, and will also include guidance on hydrogen transportation. The IPHE Guidelines were transferred to the International Organization for Standardization (ISO) in 2022 to develop a common global standard,[3] and a draft technical specification (ISO DTS 19870) of the "Methodology for determining the greenhouse gas emissions associated with the production, conditioning and transport of hydrogen to consumption gate" is expected to be submitted for publication by COP 28. Following this, three international standards, for production, conditioning and transport, respectively, are expected to be sequentially developed within the 2024-26 timeframe.

This will be a significant first step towards the adoption of standards on the emissions intensity of hydrogen production in regulations and certification, or as a criterion for receiving subsidies. The Hydrogen Task Force of the United Nations Economic Commission for Europe (UNECE)[4] is also investigating the opportunity for a common methodology for standards based on the United Nations Resource Management System (UNRMS), a voluntary global standard for integrated and sustainable resource

[2] In this report, hydrogen includes also hydrogen-based fuels such as ammonia and synthetic hydrocarbons.
[3] ISO is a non-governmental organisation that comprises standards bodies from more than 160 countries, with one standards body representing each member country. For example, the American National Standards Institute represents the United States. The ISO Technical Committee for hydrogen technologies (TC 197) has so far published 18 ISO standards and is currently developing 24 more for systems and devices for the production, storage, transport, measurement and use of hydrogen. New ISO Technical Subcommittee ISO/TC 197/SC 1 "Hydrogen at scale and horizontal energy systems" is responsible for hydrogen sustainability aspects. It began development of the DTS 19870 in January 2023.
4 In 2023, the United Nations Economic Commission for Europe (UNECE) established a Hydrogen Task Force to promote policy dialogue, co-operation and good practices related to sustainable hydrogen within the UNECE region. The Task Force currently has three main areas of work: hydrogen standards and classification, promotion of actions along the whole value chain and synergies with energy infrastructure.

management. The Task Force aims to work on a hydrogen taxonomy based on lifecycle analysis and a Guarantee of Origin for Hydrogen, in collaboration with various organisations.

On an individual basis, governments are starting to adopt regulatory frameworks for the certification of hydrogen for producers seeking support from government programmes (see Box 3.1).

Box 3.1 Progress on hydrogen certification activities

A number of new regulatory measures related to hydrogen certification were introduced in 2022. The United Kingdom's Low-Carbon Hydrogen Standard policy was published in April 2022, with a defined emissions threshold to determine eligibility for support schemes, and the Government is now consulting on a certification scheme. The European Commission has published two Delegated Acts, one defining the conditions under which hydrogen, hydrogen-based fuels and other energy carriers can be considered as renewable fuels of non-biological origin (RFNBOs), and one for a methodology to assess GHG emissions savings from RFNBOs. In September 2022, the US Department of Energy issued draft guidance for a clean hydrogen production standard, proposing an initial lifecycle emissions target of no greater than 4 kg CO_2 equivalent (CO_2-eq)/kg H_2, but methodological details are still to be released. The extent to which these early attempts to adopt regulations are being informed by international efforts is not yet clear.

The different approaches (in criteria, scope and methodologies) of the certification schemes being implemented by countries suggest that greater co-ordination is needed to prevent different accounting methodologies becoming a barrier to the creation of a global hydrogen market. Without greater international co-ordination, different approaches to certification risk locking-in suppliers to a single off-taker and restricting trade to only that carried out under bilateral agreements.

IPHE is working with the COP 28 team on a declaration of intent to pursue mutual recognition of certification schemes of renewable and low-carbon hydrogen, to be signed at COP 28.

At the end of 2022, IPHE initiated a certification mechanisms task force, aiming to assess the conditions for interoperability of low-carbon and renewable hydrogen certification mechanisms and identify common information requirements to enable low-carbon and renewable hydrogen certification equivalency.

The IEA Hydrogen TCP Task 47 on Hydrogen Certification was approved by the TCP's Executive Committee on 28 June 2023 to work on technical matters of harmonisation of certification, and the group of experts started its activities in a kick-off meeting in July 2023. This Task will be co-led by the United States (Department of Energy) and Japan (New Energy and Industrial Technology Development Organization), with the Hydrogen Council as Task Manager (co-ordinator), and

France (Alternative Energies and Atomic Energy Commission), Germany (NOW GmbH), Australia (Department of Climate Change, Energy, the Environment and Water) and ISO as subtask leaders. This work is fully co-ordinated with the IPHE.

IRENA and RMI have published the report Creating a global hydrogen market: Certification to enable trade providing an overview of existing certification schemes and identifying gaps that may hinder the development of hydrogen trade across borders. A Hydrogen Certification 101 paper was developed by mid-2023, co-ordinated by the IPHE and the IEA Hydrogen TCP, with support from IRENA and contributions from the Hydrogen Council and Power-to-X Hub.

Beyond the technical work among these nominated initiatives, progress has been made on agreeing on some of the principles for hydrogen standards at a political level. Notably, this includes agreement among the G7 under Japan's Presidency, resulting in a Communiqué text that reads: "We will enhance our efforts to develop the rule-based, transparent global market and supply chains for low-carbon and renewable hydrogen based on reliable international standards and certification schemes adhering to environmental and social standards." This was supported by the IEA report Towards hydrogen definitions based on their emissions intensity and it builds on the initial work of the G7 Hydrogen Action Pact (G7-HAP) from 2022, including the IRENA report Accelerating hydrogen deployment in the G7, that included 15 recommendations, including "Establish common sustainability criteria for traded and supported hydrogen" and "Align methodologies for hydrogen certification".

Apart from sustainability matters, there are still many gaps in the technical and safety standards along the value chain. Since 2022, different initiatives have made progress on identifying needs for safety and technical standards, as well as any gaps, and have provided recommendations on how to address them.

In March 2023, the European Clean Hydrogen Alliance[5] Working Group on Standardisation published the Roadmap on Hydrogen Standardisation. The report contains a list of approximately 400 standardisation topics, as well as a description of the status of each topic and gaps identified by surveying the working group on standardisation.

The Hydrogen Council, a global initiative representing business, performed a gap analysis and identified more than 400 regulatory and safety gaps through desk review, interviews and expert review. This list was then refined to 13 key priority topics across 7 priority areas.

Additionally, IPHE approved the launch of two Task Forces by its Regulations, Codes, Standards and Safety Working Group, on maritime considerations and on bulk storage, which are expected to identify gaps in standards.

In addition to the development of international standards, it is critically important to ensure that all countries entering the hydrogen value chain – and especially developing markets –

[5] The European Clean Hydrogen Alliance was set up in July 2020 to support the large-scale deployment of clean hydrogen technologies by 2030. It brings together public bodies, research & technology organisations, civil society organisations, private companies and other entities.

have the capability to assess conformity with such standards. Anticipating and building the necessary technical capacities for effectively verifying compliance against the defined international standards is imperative to allow every country to rapidly begin adopting low-carbon and renewable hydrogen technologies.

Examples of initiatives towards this aim are already emerging, in particular within the UN framework. The United Nations Industrial Development Organization (UNIDO) Global Programme for Green Hydrogen in Industry, for example, supports developing countries to build such capacities, and UNIDO is conducting a series of workshops to raise awareness and outline the process for participation in international standards on hydrogen. Another example comes from the Hydrogen Task Force of UNECE: While many UNECE member states are already active partners in the IPHE, there are still 17, particularly landlocked developing countries, that have not yet participated. The Task Force is therefore working to extend the geographic reach of the IPHE by engaging these not-yet-involved UNECE member states in hydrogen-related discussions and activities.

WHAT MORE NEEDS TO BE DONE?

The past year has seen notable developments of international standards for renewable and low-carbon hydrogen, led by the IPHE and the ISO, but a sizeable number of standards are yet to be developed. Further progress is also needed in developing and agreeing safety and operational standards.

While the finalisation of more concrete plans will take time, governments should continue to work closely through existing forums for collaboration and, where needed, commit to adequately resource workplans that can facilitate improved dialogue and co-ordination. Support from relevant governments and industries (for example on pre-normative research to accelerate the development of the relevant standards) could accelerate the approval and implementation of the standards, thereby accelerating hydrogen deployment. At the same time, it will be essential to ensure that all countries have the technical capacity to verify compliance with hydrogen standards, including through capacity building and technical assistance for developing countries.

RECOMMENDATION H1 HAS BEEN UPDATED AS FOLLOWS:

Governments and businesses should provide financial and human resources for the development and implementation of a comprehensive portfolio of national and international standards, based on a well-articulated plan that defines resource needs. Governments should also work towards the adoption of a common methodology to calculate the carbon footprint of the hydrogen value chain to facilitate mutual recognition and interoperability of certification systems. Governments should anticipate building technical capacity of their national systems to verify compliance with international hydrogen standards.

CO-ORDINATING ACTION TO CREATE TARGETED DEMAND FOR LOW-CARBON AND RENEWABLE HYDROGEN, STARTING WITH EXISTING INDUSTRIAL APPLICATIONS

OVERVIEW

Last year, we recommended that countries and companies should co-ordinate around increased commitments for the use of renewable and low-carbon hydrogen in sectors where hydrogen is currently used, and share learning to accelerate early deployment in new priority application sectors for hydrogen[6]. At COP 27, countries under the Hydrogen Breakthrough agreed to strengthen the demand signal, by co-ordinating the agreement and announcement of packages of firm public and private commitments for the large-scale use of renewable and low-carbon hydrogen to displace fossil fuel use in a wide range of applications. Countries are expected to announce aggregated commitments by COP 28 and to update them at subsequent COPs. The First Movers Coalition (FMC), the Mission Innovation Clean Hydrogen Mission (CHM) and the Clean Energy Ministerial Hydrogen Initiative (H2I) were nominated by countries to co-ordinate this work.

WHAT PROGRESS HAS BEEN MADE?

We assess that minimal progress has been made against our recommendation on demand creation from last year, with very few additional commitments by countries and companies and a continued lack of specificity in such commitments.

International co-operation is vital for creating demand for renewable and low-carbon hydrogen use, particularly in priority sectors like heavy industry (especially chemicals and steel), maritime shipping, aviation, seasonal electricity storage, and potentially in segments of heavy-duty trucking, where competition may hinder decarbonisation efforts. Co-ordinated demand-creating policies can send a stronger signal to mobilise investment in low-carbon and renewable hydrogen production. Collaboration also allows actors to share experience in establishing a more secure, diversified demand for hydrogen over time. Both are crucial to achieving economies of scale and accelerating cost reductions on the supply side. Various initiatives are in place to facilitate co-ordination between countries and private sector stakeholders.

Among the private sector-led initiatives, FMC gained 29 new commitments since COP 27, of which 18 are relevant to hydrogen demand in sectors such as aviation, shipping, steel

[6] In last year's report, priority applications were identified as applications where emissions are hard to abate, and where there are limited viable clean energy alternatives, including heavy industry, maritime shipping, aviation, seasonal electricity storage, and segments of heavy-duty trucking.

and trucking. FMC is currently assessing the potential range of demand for hydrogen that could result from the pledges made by its members by 2030, with the aim of completing the assessment by COP 28.

The Green Hydrogen Catapult (GHC), another relevant private sector initiative, has welcomed 3 new members since COP 27, bringing its total membership to 11 organisations. The GHC is conducting feasibility studies for delivering hydrogen-based fuels to ports and aims to announce the first shipping corridor this year. Additionally, the GHC is developing a "Book & Claim" system to aggregate demand from numerous stakeholders, enabling the procurement of ships capable of operating with hydrogen-based fuels and the development of necessary infrastructure.

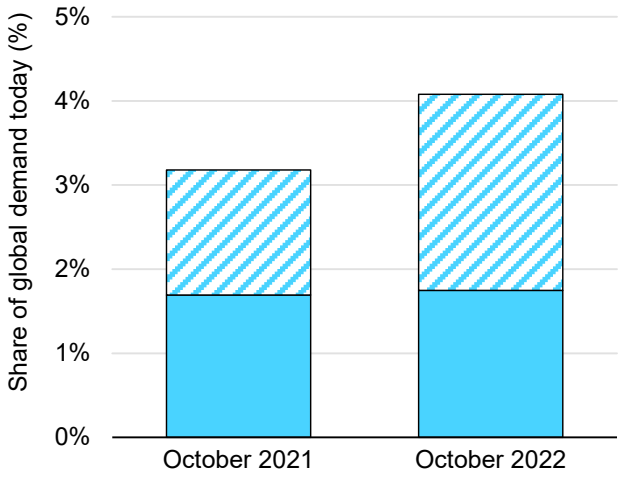
With regards to government-led initiatives, Spain joined the Mission Innovation CHM, increasing the number of members to 20. No new members have joined the H2I since our last report. The Mission Innovation Hydrogen Valley Platform, which showcases hydrogen valley[7] projects around the world, was relaunched in May 2023. If all of the 83 valleys showcased on the platform are realised, they will unlock significant demand for renewable and low-carbon hydrogen (for more on progress through the Mission Innovation CHM, see the following section). H2I has initiated the International Hydrogen Trade Forum to stimulate discussion between importing and exporting countries, including through engagement with Clean Energy Ministerial (CEM) and non-CEM government members.

Progress on international co-operation to establish global targets for demand creation for low-carbon and renewable hydrogen has been limited. Such targets have been implemented or considered by some individual countries and political entities. The European Union has agreed targets for stimulating demand for renewable fuels of non-biological origin (RFNBOs), including that 42% of hydrogen demand in industry must be met with RFNBOs by 2030. Additionally, targets have been set for at least 1% RFNBO in total energy demand in transport and 1.2% of aviation fuels by 2030. While these targets are mandatory for EU member countries, national policies must now be implemented to meet them. India's National Green Hydrogen Mission, released in April 2023, did not include previously announced quotas for renewable hydrogen in fertilisers, refining and steel, but these remain under discussion and could be adopted in the near future. As the figure below shows, the sum of these targets by all relevant countries so far corresponds to only a few percent of current global hydrogen demand, and rose only from 3% to 4% between 2021 and 2022.

We are not aware of any attempts by groups of countries to agree targets for the near-term deployment of low-carbon and renewable hydrogen in industrial applications or refining, which account for nearly all of current global hydrogen use. This is a significant missed opportunity for rapidly scaling up the low-carbon and renewable hydrogen economy.

[7] A hydrogen valley is a geographical area – a city, region, island or industrial cluster – where several hydrogen applications are combined together into an integrated hydrogen ecosystem that consumes a significant amount of hydrogen, thus improving the economic viability of the project.

Figure 3.2 Sum of countries' targets for the use of low-carbon and renewable hydrogen in industry and refining, as a percentage of total hydrogen demand



Notes: Dashed areas denote the upper value of targets which are provided as a range. With regards to the contribution of the European Union, the lower value corresponds to the Fit for 55 package, while the upper range refers to the targets set out in the REPowerEU plan. The dashed area also includes the contribution of the announced mandatory quotas for renewable hydrogen use in industry in India, although they are not yet featured in a policy document.

Source: IEA (2022), Global Hydrogen Review 2022.

Despite some individual progress, demand targets for low-carbon and renewable hydrogen remain very low

WHAT MORE NEEDS TO BE DONE?

Overall, progress on the creation of demand for renewable and low-carbon hydrogen has been limited. Government targets have fallen short of initial announcements, with no new targets being declared in the past year. Furthermore, there is a lack of funded policies or mandatory regulations in place to meet these targets. Current efforts from countries have mostly been on an individual basis, with minimal collaboration in setting targets either in total or within specific sectors, or in establishing policies to meet those targets. In the private sector, some progress has been made to clarify the expected demand from existing initiatives, with further developments expected by COP 28.

Both governments and companies need to strengthen their collaboration around measures that will send a stronger collective demand signal, including moving from targets to policies and from commitments to contracts.

RECOMMENDATION H2 HAS BEEN RESTATED AS FOLLOWS:

Governments and companies should co-ordinate internationally to increase commitments for the use of low-carbon and renewable hydrogen in sectors where hydrogen is already used, supported by specific policies and purchase agreements, to collectively send a strong demand signal and mobilise investment in production. In new priority application sectors, countries should share learning to accelerate early deployment. This should be done in a manner that ensures a level playing field in international trade.

DRIVING GLOBAL EXPANSION AND KNOWLEDGE-SHARING OF HYDROGEN DEMONSTRATION PROJECTS FOR DIVERSE HIGH-PRIORITY SECTORS

OVERVIEW

Last year, we recommended that governments and companies should work together to dramatically increase the number and geographical distribution of hydrogen demonstration projects, and to ensure that these appropriately cover each of hydrogen's high-value end-use sectors[8]. At COP 27, countries under the Hydrogen Breakthrough agreed to drive such an increase, backed by mechanisms to broaden and more rapidly share learning from projects, and committed to report progress annually at subsequent COPs. The Mission Innovation CHM was nominated by countries to co-ordinate this work.

As they make use of a relatively nascent set of technologies, renewable and low-carbon hydrogen production and use processes require the active involvement of first movers who are willing to rapidly innovate, pay higher prices, take risks and adapt to a changing regulatory environment, all of which can be facilitated by greater collaboration. First movers make an essential contribution to accelerating the understanding and implementation of hydrogen-based solutions across industries, and governments can play a crucial role by providing the necessary platform for knowledge exchange to take place effectively. By fostering collaboration and creating supportive frameworks, governments can facilitate the rapid international dissemination of best practices, thereby encouraging innovation and driving the widespread adoption of hydrogen as a sustainable solution.

[8] The emphasis on demonstration projects over research in this section is driven by the large number of hydrogen technologies, particularly on the end-use side, that are at demonstration stage and that could unlock large demands for hydrogen in priority sectors. Demonstration projects can enable real-world application and validation of hydrogen technologies, producing practical insights and instilling confidence among governments and companies to invest in and expand the use of hydrogen technologies on a larger scale.

WHAT PROGRESS HAS BEEN MADE?

We assess that minimal progress has been made against our recommendation from last year, with pilot projects being located mostly in developed countries.

The 20 countries participating in the Mission Innovation CHM have a long-standing shared goal of identifying at least 100 large-scale integrated low-carbon and renewable hydrogen valley projects worldwide by 2030, with the aim of establishing a global network by COP 28. These projects will test the delivery of different production, storage and transport methods and end-use applications, towards the objective of reaching critical scale and unlocking rapid deployment.

Further, the CHM aims to specifically target new projects in developing countries, supported by the development of a framework that can facilitate sharing lessons learned, identifying gaps and accessing support, including a joint call for research and innovation projects. To enhance collaboration between projects, the CHM aims to stimulate knowledge exchange between the different valleys with dedicated international workshops, while simultaneously monitoring the development of the valleys. This monitoring activity has the potential to surface knowledge about good (and bad) practices related to hydrogen valleys, creating a learning resource for future developers worldwide.

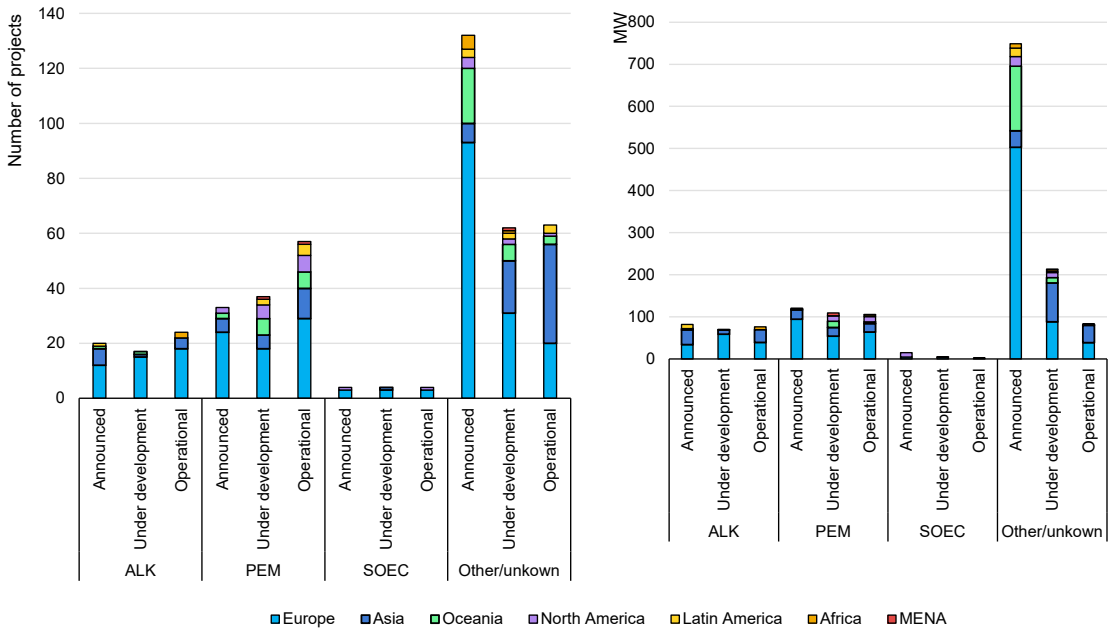
The Mission Innovation Hydrogen Valley Platform, showcasing hydrogen valley projects around the world, was relaunched in May 2023 and by the end of July 2023 included 83 valleys from 33 countries. Moreover, three-quarters of the listed valleys are in Europe, and the limited number of projects in the Global South within the platform leaves room for speculation regarding the existence of initiatives in these regions. Further collaboration between the platform, regional hubs of multilateral development banks (MDBs) and other local institutions in the Global South could enhance the monitoring and assessment of initiatives.

Pilot projects[9] for renewable hydrogen production are still limited primarily to Europe (59% of the total number of projects) and Asia (21%). As much as 50% of 1.6 GW of planned or installed capacity of electrolysers of pilot project size is concentrated in just four countries: China (243 MW), Germany (202 MW), Spain (191 MW) and Australia (185 MW). Thirty-nine countries account for the remaining 50%.

The 14 pilot projects for low-carbon hydrogen production are similarly unevenly distributed, with the largest number of projects in North America (9), followed by Europe (3). Only three projects are currently operational – in Canada, China and France.

[9] Renewable hydrogen pilot projects are defined here as any electrolysis projects with a capacity below 10 MW for any technology (alkaline, proton exchange membrane [PEM] or solid oxide electrolyser cell [SOEC]), commissioned after 2020 or planned to be commissioned by 2030, for a total of 453 projects considered. Low-carbon hydrogen pilot projects are here defined as any carbon capture, utilisation and storage (CCUS) project for hydrogen with a capture rate below 100 kt of CO_2 per year.

Figure 3.3 Status of renewable hydrogen pilot projects as of late 2022: Capacity (left) and number (right) of projects, by electrolyser type and region



Notes: Alk = Alkaline; MENA = Middle East and North Africa; PEM = Proton Exchange Membrane; SOEC = solid oxide electrolyser cell. Only renewable hydrogen pilot projects are presented due to the small number of low-carbon hydrogen projects and significant uncertainties about their production capacity. Alk = Alkaline, PEM = Proton Exchange Membrane, SOEC = solid oxide electrolyser cell.

Source: IEA and IRENA analysis based on (2022), Hydrogen Projects Database, (accessed September 2023).

The majority of the capacity of renewable hydrogen pilot projects is still in the announcement phase.

It should be noted that a large majority of the capacity is still in the announcement phase (967 MW), while only 396 MW are under development (either have reached final investment decision or are under construction). Only 268 MW are currently operational.

Last year we reported that there was a lack of emphasis on industrial and maritime applications of hydrogen in international efforts to create hydrogen valleys, and this appears still to be the case. While no end use is mentioned for around 19% of the capacity of the renewable hydrogen pilot projects identified in the 2022 IEA database, 51% of the remaining projects target transport, and only 19% target refining and heavy industry (with the remaining projects targeting other industry [14%], grid injection and domestic heating [12%], and power generation [5%]). This reflects the fact that projects for hydrogen production intended for use in industrial applications tend to be larger in size than those aiming to use it into transport applications (typically small hydrogen refuelling stations).

WHAT MORE NEEDS TO BE DONE?

In conclusion, the current state of the global hydrogen pilot projects pipeline reveals a lack of geographical dispersion and sectoral balance. The end-use applications of hydrogen projects largely focus on transport, while other priority sectors (heavy industry, maritime shipping, aviation, seasonal electricity storage) receive limited attention. Moreover, projects still struggle to move from the announcement phase to investment and construction. This makes the exchange of information and sharing of best practices challenging.

The establishment of a conceptual framework to exchange best practices by COP 28 is a positive step forward. This framework will signal to developers the possibility to hit the ground running when it comes to sharing valuable information and experiences. However, for this potential to be realised, the conceptual framework must be underpinned by a practical framework. Knowledge-sharing structures, like the one planned within the Mission Innovation CHM, should be put into practice as soon as possible.

Effective international collaboration between governments, developers and the research community is required throughout development and demonstration. This collaboration would benefit from a stronger focus on priority sectors, where the growing weight of evidence suggests hydrogen will be of greatest value, and should foster partnerships and knowledge exchange among key actors in projects focused on these sectors.

RECOMMENDATION H3 HAS BEEN RESTATED AS FOLLOWS:

Governments and companies should work together to dramatically increase the number and geographical distribution of hydrogen demonstration projects and to ensure that these appropriately cover each of hydrogen's high-value end-use sectors, including maritime shipping, heavy industry and long-duration energy storage. Governments and the private sector should agree on minimum reporting principles to guide a deeper and more rapid sharing of knowledge among these demonstration projects and with the broader stakeholder community, including a commitment to share the lessons learned from all publicly funded demonstration projects.

COLLABORATE FOR THE RAPID SCALE-UP OF CONCESSIONAL FINANCE FOR LOW-CARBON AND RENEWABLE HYDROGEN PROJECTS IN DEVELOPING ECONOMIES

OVERVIEW

Last year, we recommended that governments should greatly increase the scale of technical and financial assistance for hydrogen projects, helping to accelerate deployment in developing countries. At COP 27, countries under the Hydrogen Breakthrough agreed to enhance international assistance by co-ordinating and facilitating access to increased concessional finance and other mechanisms that address obstacles to investment, including communicating a portfolio of such mechanisms by COP 28. To lead this activity, countries nominated UNIDO and the World Bank.

WHAT PROGRESS HAS BEEN MADE?

We assess that modest progress has been made against our recommendation from last year, with international financial institutions committing at least USD 6.4 billion to support hydrogen in developing countries.

UNIDO, in collaboration with the World Bank and IRENA, is conducting a mapping exercise that tracks existing financial and technical assistance support towards hydrogen projects in developing countries. This will cover initiatives undertaken by MDBs, funds, international technical agencies, national development agencies and other initiatives (e.g. H2Global) that have active programmes or are developing them. Preliminary results of the mapping exercise show that grants and concessional loans are the most common instrument, mainly focused on the upstream part of the value chain. On the downstream segment, grants are mainly directed to the chemical, metallurgy and road transport sectors.

The World Bank, Global Infrastructure Facility (GIF) and the OECD are currently (at the time of writing) preparing a study to review the existing literature on major market trends, financing challenges, investment needs and the type of financing required in the hydrogen sector.

Given the relatively early stage of development of most major renewable and low-carbon hydrogen projects, the development of such knowledge can help better advise international financial institutions, governments, technical partners and industry in understanding and identifying appropriate financial instruments to overcome different barriers facing projects.

The World Bank launched the Hydrogen for Development Partnership (H4D), a new global partnership to boost the deployment of low-carbon and renewable hydrogen in developing countries by providing practical advice to national governments. H4D is open to all hydrogen stakeholders and already counts 31 leading industry associations, government investment vehicles, hydrogen hubs and research institutes as partners. The H4D partnership has four work streams: (1) technology, infrastructure and systems integration;

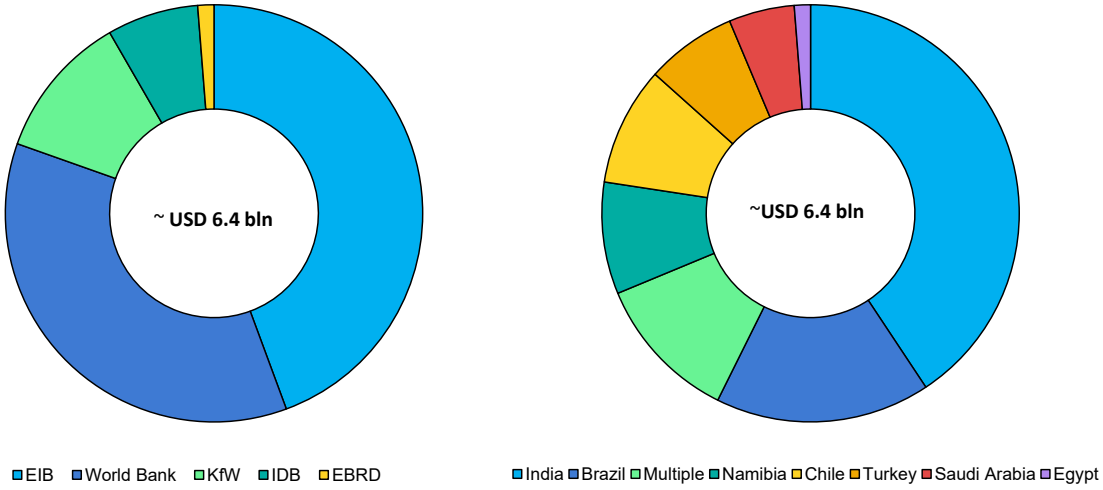
(2) policy and regulations; (3) investments, financing, business models and procurement; and (4) socio-economics and sustainability. Working groups are developing specific products across these areas.

To further enhance collaboration, the Africa Green Hydrogen Finance Accelerator Forum, held in April 2023, convened 200 stakeholders from development finance institutions, governments, project developers and bilateral partners to discuss finance and de-risking solutions for green hydrogen projects in Africa. Recommendations included scaling up blended financing, establishing an African renewable energy and green hydrogen economy financing vehicle, increasing the volume of guarantees, and encouraging importing countries to create an inclusive market for renewable hydrogen. The Forum was organised by the Mauritania Ministry of Petroleum, Mines and Energy and the Africa Green Hydrogen Alliance (AGHA) with the support of the Green Hydrogen Organisation (GH2) and the World Bank.

Many new commitments to mobilise investment in hydrogen projects have been made in the past year, marking a crucial step towards advancing the hydrogen economy worldwide. Since March 2022, around USD 6.4 billion has been committed by major public financial institutions to support hydrogen development in developing countries (Figure 3.4)[10], with India being the main recipient to date, taking in almost half of all commitments. This includes USD 2.9 billion worth of commitment by the European Investment Bank (EIB) to develop renewable hydrogen projects in Brazil, India and Namibia. Additionally, the World Bank is providing USD 1.5 billion to India and USD 150 million to Chile to support early-stage renewable hydrogen projects through the provision of financing, risk-mitigation and capacity building.

[10] Additional commitments are in the pipeline which are likely to increase this figure in the coming months.

Figure 3.4 Financial commitments by bilateral and multilateral development finance institutions for hydrogen projects in developing countries by agency (left) and country (right), August 2023



Notes: EBRD = European Bank for Reconstruction and Development; EIB = European Investment Bank; IBRD = International Bank for Reconstruction and Development; IDB = Inter-American Development Bank. As additional announcements are in the pipeline from organisations such as the World Bank Group, Asian Development Bank, and other multilateral and bilateral development finance institutions, the USD 6.4 billion committed thus far is expected to increase over the next year. Also note that this figure is likely an underestimate of the total funds committed to date. This is because, while the list of tracked commitments aims to be exhaustive, it is possible that some commitments may have been inadvertently missed. In addition, much of the support for renewable and low-carbon hydrogen is coupled with broader clean energy initiatives, making it challenging to determine the exact volume going to hydrogen. For example, Climate Investment Funds (CIF) committed USD 70 million to support clean energy deployment in Brazil. As the exact amount going towards hydrogen is not known, this commitment has been excluded from the figure above.

Sources: IEA and IRENA analysis based on data from European Investment Bank (a), European Investment Bank (b), World Bank, IEA, and European Bank for Reconstruction and Development.

International financial institutions have committed at least USD 6.4 billion to support hydrogen in developing countries.

Financial support of such scale and scope in the sector is unprecedented given that it is at such a nascent stage of development. However, additional private finance is needed to bridge the overall investment gap in developing countries, estimated to be between USD 37-59 billion per year until 2030.[11] Attracting such finance will require appropriate policy frameworks, which international assistance can help to design.

In many developed economies, hundreds of billions are expected to be mobilised by governments in the form of domestic subsidies to support local projects, thereby stimulating additional private investment. In contrast, governments in many developing economies may be more fiscally constrained and less able to undertake similar measures.

[11] This includes investment needs in developing countries for electrolysers (new additions as well as stock replacements), hydrogen infrastructure (pipelines, new infrastructure needs for transporting hydrogen, bunkering facilities and hydrogen fuelling stations for road transport), long duration energy storage, and facilities for hydrogen-based ammonia and methanol.

Therefore, without additional support from international public financial institutions, most new financing for hydrogen is expected to be concentrated in developed countries, like the United States and EU member countries. In the near term, the concentration of financial capital in wealthier nations can further fuel existing imbalances by diverting attention and funding away from potential hydrogen projects in developing countries. But as projects in developed countries successfully reach scale, attain substantial technological advancements, and realise cost reductions, the resulting benefits have the potential to ripple out globally, ultimately rendering future hydrogen production investments in developing countries more feasible and accessible.

WHAT MORE NEEDS TO BE DONE?

To ensure the opportunity to produce and deploy low-carbon and renewable hydrogen at large scale in developing countries is not missed, collaboration and co-ordinated efforts among governments, financial institutions and other relevant stakeholders will be needed both to scale up financing through existing models, and to develop innovative financing models that take into account the local context in each country. The improved mapping of the various actors, instruments and funds to support the development of hydrogen projects that is now underway is a welcome development, but this must not remain solely an analytical exercise. It will be crucial for governments and financial institutions to use this knowledge to identify the most effective ways for international co-operation to help unlock financing for low-carbon and renewable hydrogen projects in developing countries, and to expand and replicate these approaches.

Additionally, the initiatives discussed above aim to broaden the understanding of the hydrogen financing landscape, address obstacles and associated risks, and explore successful financing models that have not been investigated before. By capitalising on the new-found financial support, technical expertise, and knowledge-sharing offered through these initiatives, developing countries can accelerate the progress of their hydrogen sectors.

RECOMMENDATION H4 HAS BEEN UPDATED AS FOLLOWS:

Governments, MDBs and relevant technical partners should work to identify viable projects that are being delayed by high costs of capital and other obstacles to investment, then identify best practices to help unlock their progress. This should be supported by appropriate technical assistance programmes to assist governments with policy design for the further scale-up of projects.

RECOMMENDED REPORTS

We recommend the following reports for more detailed descriptions of the technologies for low-carbon and renewable hydrogen and of the actions that countries and businesses can take individually.

The Future of Hydrogen (IEA, 2019)

Making the Hydrogen Economy Possible: Accelerating Clean Hydrogen in an Electrified Economy (Energy Transitions Commission, 2021)

Global Hydrogen Review 2022 (IEA, 2022)

Geopolitics of the Energy Transformation: The Hydrogen Factor (IRENA, 2022)

Global Hydrogen Trade to Meet the 1.5°C Climate Goal: Green Hydrogen Cost and Potential (IRENA, 2022)

"Green hydrogen: A guide to policy making" series ([1], [2], [3]) (IRENA, 2020- 2022)

International Trade Rules for Hydrogen and its Carriers: Information and Issues for Consideration (IPHE, 2022)

Roadmap on hydrogen standardisation (European Clean Hydrogen Alliance, 2023)

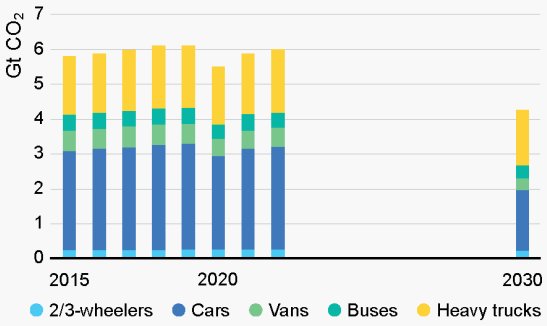
Creating a global hydrogen market: Certification to enable trade (IRENA, 2023)

Towards hydrogen definitions based on their emissions intensity (IEA, 2023)

ROAD TRANSPORT

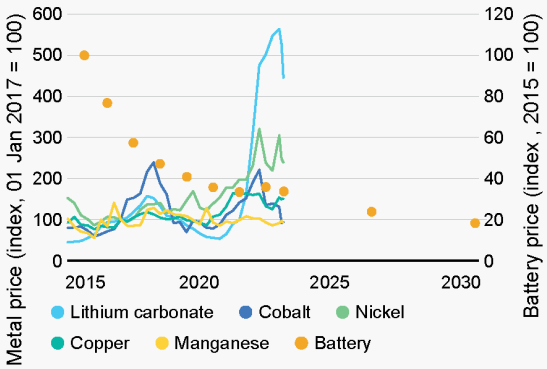
While road transport emissions continue to rebound towards pre-pandemic levels, sales of electric passenger cars – currently 14% of total car sales – have been doubling every 1.2 years. If this rate continues, the deployment of electric cars will exceed what is required under a net zero scenario, reaching 65% of new sales before 2030. Electrification across other vehicle types, as well as policies to reduce car use, will also be needed.

Emissions



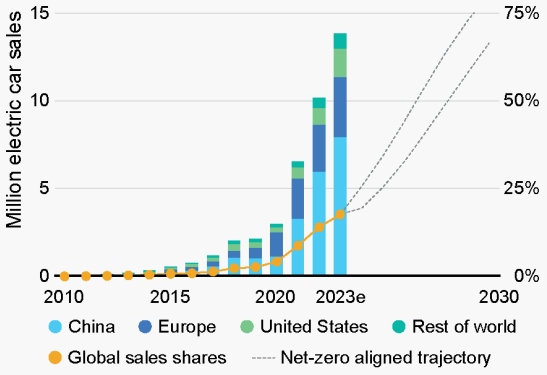
- Direct CO_2 emissions from fossil fuel combustion in the road sector have risen by 200 Mt since 2015. Emissions need to fall by nearly one-third by 2030 to align with the IEA Net Zero Emissions by 2050 Scenario (NZE Scenario).

Costs[1]



- Variability in the price and availability of critical minerals largely explains why electric vehicle (EV) battery price reductions have stalled in recent years.
- Recent falls in critical mineral prices could lead to a reduction in battery prices in 2023, hastening purchase price parity for electric cars, which is expected to occur before 2030 in small and medium segments.
- The total cost of ownership (TCO) of electric buses and trucks is likely to be lower than their diesel counterparts across nearly all medium- and heavy-duty segments by 2030 in Europe, the United States and China.

Deployment



- The global market share of EVs[2] in other vehicle categories is growing, but will need to continue growing rapidly to achieve net zero ambitions:

Vehicle category	EV sales share	
	2022	2030
Two- and three-wheelers	15%	At least 80%
Passenger cars	14%	At least 65%
Light commercial vehicles	3.6%	At least 70%
Buses	4.4%	At least 60%
Medium- and heavy-trucks	1.2%	At least 33%

[1] Metal prices and historical battery prices are from IEA (2023), Energy Technology Perspectives 2023. Future battery prices are based on implied cost reductions based on a 17% learning curve, from BNEF, 2023.
[2] Unless otherwise specified, the term electric vehicle is used to refer to both battery electric and plug-in hybrid electric vehicles, but does not include fuel cell electric vehicles.

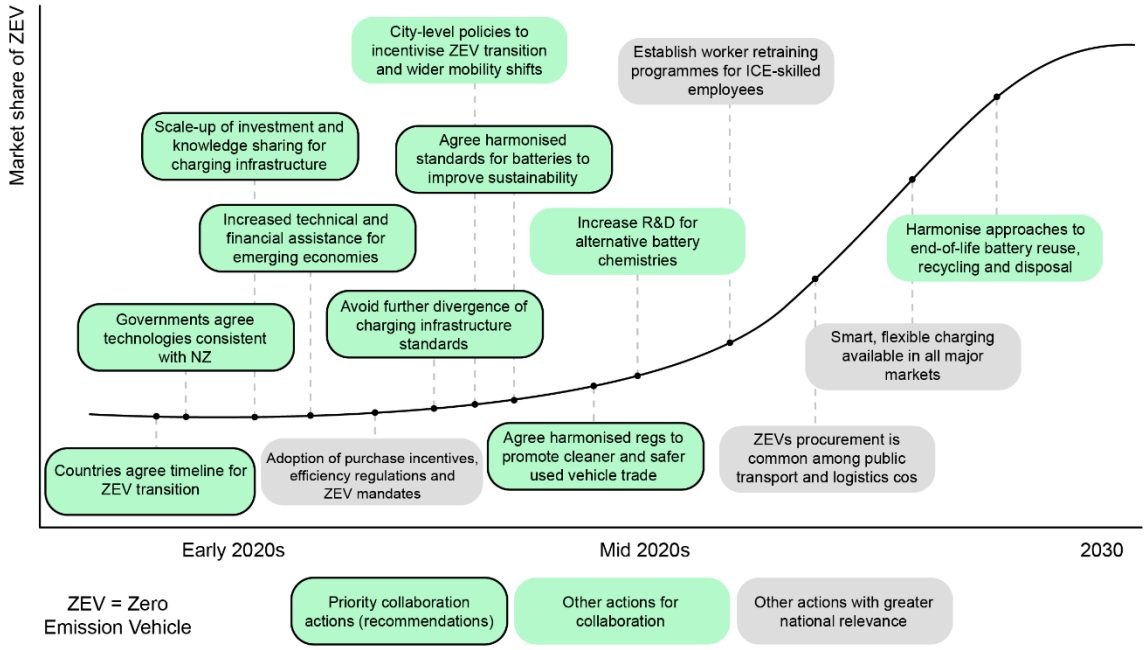
STATE OF INTERNATIONAL COLLABORATION

In last year's report, we identified international collaboration in the areas of setting a long-term vision, finance and investment, supply chains, infrastructure and trade conditions as being important for the road transport sector, and made recommendations on the most urgent and high-impact opportunities in need of international collaboration in each of those areas. In this report we assess progress against those recommendations. Our assessment is summarised in the table below, and the following sections address each area of international collaboration in turn.

Area	What progress has been made?	What more needs to be done?	2023
RT1. Long-term vision	• Increased membership of multiple initiatives setting voluntary commitments for zero emission vehicle (ZEV) adoption. • Notable expansion of commitments beyond electric cars, including 5 corporate members of EV100+ and 14 corporate members of FMC Trucking.	• Translate voluntary commitments into binding policies for all major markets and secure broader support from original equipment manufacturers (OEMs). • Expand commitments into new vehicle segments, including 2- and 3-wheelers.	Modest
RT2. Finance and investment	• ZEV-Transition Council (ZEVTC) International Assistance Taskforce (IAT) and the Collective for Clean Transport Finance providing mapping and technical assistance, with a particular focus in Sub-Saharan Africa and India. • Expansion of technical and financial assistance, notably via the GEF-7 Global Electric Mobility Programme and the World Bank's Global Facility to Decarbonise Transport.	• Scale up support globally, including in product supply, policy and standards, through stronger co-ordinated working. • Further co-ordinate to scale, accelerate and de-risk investment, reduce cost of capital, and mobilise companies. • Countries should better track project-level key performance indicators to guide future policies and assistance efforts.	Modest
RT3. Supply chains	• Co-ordination on EV battery supply chain sustainability by the Global Battery Alliance (GBA) • UNECE developing methodology for measuring GHG emissions, covering the entire automotive life cycle.	• Greater global harmonisation of sustainability standards (i.e. battery carbon footprint, responsible sourcing) and common, interoperable standards for digital product passports (i.e. data governance). • Support data & research on key obstacles and policies for enhancing circularity in battery value chains.	Modest
RT4. Infrastructure	• Establishment of ZEVTC taskforce to facilitate collaboration on charging infrastructure deployment. • ZEVWISE Coalition sharing knowledge and expertise in the medium- and heavy-duty segments, including infrastructure deployment and financing.	• Agree on a set of priority areas for scaling up technical and financial assistance and design an implementation plan for delivery. • Design regional roadmaps that lay out the needs for infrastructure deployment for trucks and buses.	Modest

Area	What progress has been made?	What more needs to be done?	2023
RT5. Trade conditions	• UNEP given a formal charter by the UN Environment Assembly to pursue policy-oriented data collection and research on used vehicle quality standards.	• Exporting and importing countries should convene to agree on an international harmonised framework on minimum standards on used vehicles, and establish a publicly accessible database for tracking.	Good

Figure 4.1 Critical path to 2030 for the road transport sector



ALIGNING THE PACE OF THE TRANSITION INTERNATIONALLY TO SHIFT INVESTMENT AND ACCELERATE COST REDUCTION

OVERVIEW

Last year, we recommended that governments should agree on a timeline by which all new road vehicle sales should be zero emission, with companies committing to the same timelines for vehicle production. We noted that greater co-ordination would achieve a faster shift of investment throughout the global industry, accelerating the reduction in cost of zero-emission vehicles. At COP 27, countries under the Road Transport Breakthrough agreed to work together to commit to and implement common and co-ordinated targets and measures that send a collective global market signal in support of a Paris Agreement-

aligned ZEV transition, and to review progress at COP 28. They nominated the Accelerating to Zero (A2Z) Coalition to co-ordinate across the six initiatives listed below, and to review and communicate progress by COP 28:

Initiative	Scope	Target	Stakeholders
ZEV declaration	LDVs	100% ZEV sales for cars and vans by 2035 in leading markets and by 2040 globally, at dates corresponding to timelines required to stay on track with Paris Agreement goals.[1]	Corporate & public sector (city, state, national)
Electric Vehicles Initiative	LDVs & HDVs	100% ZEV civil government ownership & operations by 2035 in 9 out of 16 EVI member countries (Zero-Emission Government Fleet Declaration).	Countries (16)
EV100	LDVs	100% ZEV (electric) signatory owned & contracted van and MDV fleet (<7.5t) by 2030. Establish charging infrastructure for employees & customers by 2030.	Corporate (>100)
EV100+	HDVs	100% ZEV MDV purchases by 2030 and 100% ZEV MDV operations by 2040 in leading markets (OECD, China, India).	Corporate (5)
Global MoU on ZE-M/HDVs	HDVs	30% ZEV M/HDV sales by 2030 in signatory countries and by Non-State Actor endorsers.100% ZEV M/HDV sales by 2040. 100% ZEV M/HDV operations by 2050.	Corporate & public sector (state, national)
First Movers Coalition's Trucking Commitments	HDVs	100% ZEV MDV and 30% ZEV HDV signatory purchases & contracted fleets by 2030. 100% ZEV M/HDVs for owned and contracted operations by 2040.	Corporate (14)

WHAT PROGRESS HAS BEEN MADE?

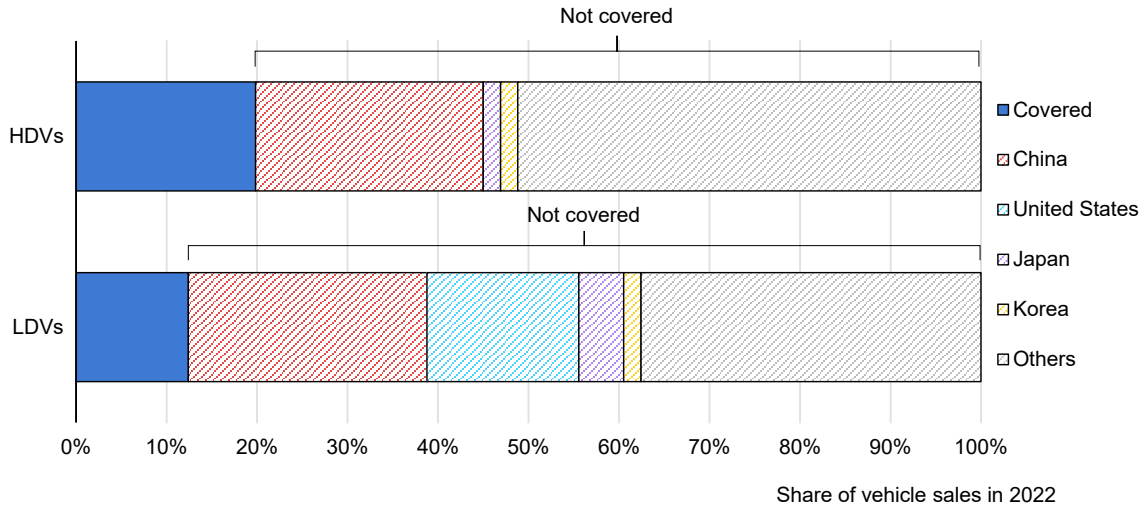
We assess that modest progress has been made against our recommendation from last year.

The ZEV declaration, first signed at COP26 and hosted by the A2Z Coalition,[2] continues to engage and attract signatories, with more than 220 signatories as of August 2023, up from 170 in May 2022. National signatories alone make up 12% of the global light-duty vehicle (car and van) market. The coalition serves as a platform for signatories to co-ordinate, align activities and amplify progress, and has been charged with tracking and reporting on progress in implementation ahead of COP 28.

[1] In line with modelling by IRENA, IEA and the ICCT.
[2] The A2Z Steering Committee comprises representatives of the UK Department of Energy Security and Net Zero, ClimateGroup, the DriveElectric Campaign, and the ICCT.

The move to zero-emission medium- and heavy-duty vehicles (M/HDVs) is also picking up pace, with the Global MoU on ZE-M/HDVs[3] making major strides in attracting national government signatories and corporate/sub-national endorsers. In 2022, 11 additional countries – among them the United States – signed the Memorandum of Understanding, bringing the total number of countries and territories among the signatories to 27. These now account for 20% of total annual sales of new M/HDVs worldwide, up from 5% previously. The Global MoU has endorsements from more than 75 regional government, M/HDV manufacturers, fleet owners and operators, among others. It is supported by technical work by the Smart Freight Centre, which leads the Sustainable Freight Buyers Alliance,9 and within this, the Fleet Electrification Coalition.[10]

Figure 4.2 Coverage of initiatives of light- and heavy-duty vehicle sales



Notes: LDVs = light-duty vehicles, including cars and vans; HDVs = heavy-duty vehicles, including buses and medium- and heavy-duty trucks. Coverage is based only on government signatories to the ZEV declaration (LDVs) and Global MoU on ZE-M/HDVs (HDVs) as the principal government initiatives aggregating commitments to net zero in the road transport sector.

Membership of ambitious collective initiatives is growing, but key automotive markets, such as Japan, Korea and China, are not yet signatories to any of the major commitments.

Commitments on the electrification of corporate fleets also progressed through the Climate Group's initiatives EV100 (for LDVs) and EV100+ campaign (for M/HDVs). As of May 2023, EV100 had 130 corporate members. The EV100+ campaign, launched in September 2022, collaborates with Drive to Zero and the Smart Freight Centre's Fleet Electrification Coalition, as well as the Global MoU on ZE-M/HDVs on policy-related issues, utilising the strength of both networks.

The initiatives outlined above have distinct targets and memberships, and complement political commitments made by national governments in initiatives such as the ZEV

3 The Global MoU was established in 2021 by CALSTART's Drive to Zero programme and the Dutch government.

declaration (which also includes corporate signatories) and the Global MoU on ZE-M/HDVs. Furthermore, engagement with corporate membership spans the full electric mobility ecosystem through initiatives such as the First Movers Coalition's Trucking Initiative, and the Fleet Electrification Coalition. The targets set by such initiatives – like the ZEVWISE effort to scale up the zero-emission truck market to between 100 000 to 1 million trucks in the very near-term – can be leveraged to achieve ambitious longer-term ZEV sales penetration targets.

Further international efforts to support the electrification of government fleets include the Zero-Emission Government Fleet Declaration, launched at the 2022 Clean Energy Ministerial by the Electric Vehicles Initiative (EVI).

International forums have also resulted in multilateral pledges to abate road sector CO_2 emissions. The Major Economies Forum in April 2023 featured a collective ZEV goal by the European Union, France, Germany, Indonesia, Norway, the United Kingdom and the United States, that pledged to work towards more than 50% of all LDVs and at least 30% of M/HDVs being ZEVs by 2030, with a view to setting national market share goals by COP 28.

At the 2023 G7 meeting, G7 member countries reaffirmed their commitment to a highly decarbonised road sector by 2030, and to collectively reducing road transport (aggregate fleet-level) emissions by at least 50% by 2035. Future G7 and G20 summits can build upon this political momentum. Another potential opportunity for commitments to be formalised is through the United Nations Economic Commission for Europe (UNECE)'s Inland Transport Committee, which has recently been recognised by the United Nations Economic and Social Council (ECOSOC) as the inter-regional UN body for inland transport, and therefore now has the mandate to develop an ambitious mitigation strategy for the global inland transport sector, including milestones and key actions that should be taken between now and 2050. Another option to encourage formal commitments would be for parties of the UNFCCC to develop a transport-specific decarbonisation roadmap, and to use this to align and integrate national-level transport-specific (and other sector-specific) emission budgets into Nationally Determined Contributions.

WHAT MORE NEEDS TO BE DONE?

To accelerate the transition to zero-emission road vehicles, more national governments – especially those with major automotive markets – should join these initiatives and collective commitments. While public sector signatories of the ZEV declaration represent a diverse mix, including European countries and developing economies, many signatories are sub-national entities such as states, provinces and cities. Notably absent are key East Asian nations — China, Japan and South Korea — whose combined market share constitutes more than one-third of the global automotive market. Greater participation in collective commitments to a fast transition would further accelerate the reduction in cost of zero-emission vehicles.

Commitments should cover all vehicle types[4], and be supported by clear implementation plans and policies. While commitments across governments, corporations, and other organisations signal an important first step, their political or voluntary nature means that they largely remain aspirational in contrast to binding national or sub-national legislation (such as CO_2 emissions or vehicle efficiency standards,[5] or ZEV mandates). It is therefore crucial that commitments are translated into national policies, such as through standards, mandates, fiscal policies and other measures, and/or by agreeing to international legally binding instruments, such as those developed by the UNECE World Forum for Harmonization of Vehicle Regulation. It may also be valuable to incorporate conditions of membership in such initiatives into the terms of multilateral trade agreements, for instance by making a commitment to ZEV sales targets a prerequisite for membership in a multilateral group of governments enjoying mutual favoured trading status.

Commitments and investments from vehicle manufacturers often align with national policy declarations –and especially with binding regulations – as seen in California, where truck and engine manufacturers recently committed to meet the state's mandatory 100% clean truck ZEV sales by 2036. Corporate engagement initiatives show robust involvement from members, particularly those that stand to benefit most from a swift shift to electric mobility, such as charging infrastructure providers, fleet owners/operators, and shared mobility platforms. and commitment across investors (including shareholders of OEMs) has increased recently. However, it is notable that major vehicle manufacturers are largely absent from these initiatives; among the world's top eight automotive groups by sales, only two (GM and Ford) have endorsed the ZEV Declaration. This trend is likely to persist unless governments in all the major automotive markets signal firm policy commitments to transition to electric mobility. It can also be useful for civil society groups to engage with automakers to recognise the benefits of publicly committing to transitioning to ZEVs at a pace that is aligned with avoiding the worst impacts of climate change.

Most initiatives to date focus on the highest emitting road transportation sectors, namely passenger cars and vans (i.e. light-duty vehicles, which account for nearly 60% of road sector emissions), as well as buses (8%) and trucks (30%). However, as is highlighted in India's commitment to the ZEV Declaration, the importance of the 2/3-wheeler markets should not be overlooked, especially in Asian markets. Zero-emission 2/3-wheelers are already more affordable to purchase and operate than Internal Combustion Engine (ICE) 2/3-wheelers, and in the regions where they are most prevalent, they are typically heavily utilised for mobility and deliveries. Co-ordinated international commitments to a fast transition in often overlooked vehicle segments could accelerate investment and progress in the technology, in the same way as for cars.

[4] The Road Transport Breakthrough goal focuses on the potential climate, health and economic benefits of a rapid transition to electric mobility. Yet while there is recognition of the need to implement policies that reduce car dependency and encourage alternative modes of transport that are less carbon-intensive, there is far less consensus on the abatement potential of "avoid-shift" strategies.

[5] The most prominent recent example being the European Union's CO_2 emissions standards, which mandate that all new cars and vans sold from 2035 will have to have zero tailpipe emissions.

RECOMMENDATION RT1 HAS BEEN UPDATED AS FOLLOW:

Governments should agree on a timeline by which all new road vehicle sales should be zero-emission, with interim targets for countries taking into account their level of economic development and ability to scale up infrastructure. Governments should put effective and legally binding policies in place to implement these commitments. Targets should be Paris-aligned and should include all vehicle types.

PROVIDING INTERNATIONAL ASSISTANCE AND FINANCE TO SUPPORT DEVELOPING COUNTRIES IN THE TRANSITION

OVERVIEW

Rapid electrification of road vehicles across Emerging Markets and Developing Economies (EMDEs) will be essential to meeting international climate goals. Last year, we recommended that the international community should scale up technical and financial assistance to developing countries for the road transport transition at city, provincial, national and regional levels. In response, countries in the Road Transport Breakthrough made a shared commitment at COP 27 to significantly strengthen the overall offer of international assistance available to support the ZEV transition in EMDEs, and to review progress at COP 28. The Zero Emissions Vehicle Transition Council (ZEV-TC) IAT[6] was tasked with leading this effort.

WHAT PROGRESS HAS BEEN MADE?

We assess that modest progress has been made against our recommendation from last year.

At COP 27, the ZEV-TC – informed by recommendations from the 2022 Breakthrough Agenda Report, the IAT and the nearly 50 EMDE countries that participated in the 2021-22 Regional Dialogues – launched a Global Commitment alongside a package of five key actions. These are: 1) updating the current landscape of international assistance; 2) launching a ZEV Rapid Response Facility (ZEV-RRF) to provide technical support; 3) the ZEV Country Partnership model to provide ambitious EMDEs with more tailored and in-depth public and private sector support and engagement; 4) the ZEV Emerging Markets

[6] IAT members include national governments as well as leading funding and delivery partners, such as UNEP, the World Bank, the FIA Foundation, the Drive Electric Campaign, ICCT and World Business Council for Sustainable Development (WBCSD), among others.

Initiative (ZEV-EM-I) to deliver a series of private sector investment dialogues; and 5) publishing a Global ZEV Transition Roadmap at COP 28, to be updated annually.

Progress is being made on all five actions, shaped by feedback from almost 50 EMDE countries during the 2021-22 ZEV Regional Dialogues.

At COP 27, the first country partnership was launched with India, incorporating a ZEV Country Pilot initiative to strengthen public sector co-ordination. It includes launching scalable pilot projects to address gaps in the provision, as well as the ZEV Emerging Markets Initiative's India Dialogue to strengthen private sector co-ordination and collaboration with government at the federal and state levels.

While such efforts to boost and co-ordinate international assistance are moving ahead, the financial and technical needs remain substantial. This calls for co-ordinated action from governments, lending institutions, technical aid agencies and the private sector. Data on levels of technical assistance funding and finance linked to electric mobility for EMDEs is sparse, and climate finance has recently scaled up considerably, with recent announcements including the Summit on a New Global Financing Pact held in Paris in June, which was followed by a multilateral development bank (MDB) Vision Statement. While these developments may also signal increasing finance for electric mobility, there remains a major gap, with investment needing to increase substantially to accelerate the transition.

The Collective for Clean Transport Finance[7] was also established at COP 27 with the aim of supporting the most ambitious governments with capacity building, engaging with companies on ZEV supply and demand, and convening finance stakeholders from the public, multilateral and private sectors. The collective works with the initiatives outlined above, and will focus its efforts on sectoral de-risking, demand aggregation, finance blending and mobilising private investors. It is engaged in e-bus, electric freight, and general transport decarbonisation projects globally, with regional foci in sub-Saharan Africa and India.

Another major source of technical and financial support to EMDEs is the Global Environment Facility (GEF-7) funded Global Electric Mobility Programme, which provides technical and financial assistance to over 50 countries – via 32 projects – focusing on the introduction of ZEV urban transit buses and 2- and 3-wheelers and the development of related national policy and standards.

As well as country-level projects, the Global Electric Mobility Programme has four Regional Support and Investment Platforms[8] that provide technical support and financing. The Programme also consists of thematic Global Working Groups that have developed products and tools for EMDEs, including those that are subsequently disseminated via the

[7] Led by WBCSD, UNEP, the Smart Freight Centre, the World Bank's Global Facility to Decarbonise Transport, and the Nand & Jeet Khemka Foundation. The initiative will link its efforts with the ZEV-TC, Global MoU and IEA EVI; other institutions and corporations have expressed interest in joining the initiative.

[8] The platforms are led by UNEP for Africa; the ADB for Asia; the European Bank for Reconstruction and Development (EBRD) for Central Europe and the Middle East, and the Molino Centre, Chile, for Latin America and the Caribbean.

regional platforms and country projects. For example, in the past year, the IEA and the United Nations Environment Programme (UNEP) have released technical tools such as a total cost of ownership calculator and an EV charging and grid integration tool. Nine new country project (GEF-8) funding proposals further aim to broaden the scope of the programme to encompass second-hand vehicles and battery recycling.

Further assistance is provided through the World Bank's Global Facility to Decarbonise Transport, established in 2021, which now funds seven projects, two of which focus on electric mobility in India and sub-Saharan Africa. Projects reduce the cost of capital, for instance by leveraging grants, providing funding shortfalls, providing loans with a first or second loss guarantee, and blending junior and senior capital into a single finance vehicle.

In the past year, the ZEV-TC International Assistance Taskforce (IAT), with the support of the Global Fuel Economy Initiative, commissioned a report on the demand for support for electric mobility from EMDE countries to inform the development of the Global ZEV Transition Roadmap. The report identified crucial areas for enhanced policy action, including reducing the cost of capital, infrastructure development, battery recycling and sustainable supply chains. The report also noted the need for better co-ordination and pooling of resources to boost their accessibility and visibility to EMDE countries, and to develop more bankable projects, with a particular focus on urban transit buses and 2- and 3-wheelers.

The IAT also reported on the current electric mobility support offer, identifying 26 existing global and regional initiatives offering technical and/or financial support, as well as a number of gaps in geographic and thematic coverage, and a lack of accessibility and awareness of existing resources. These gaps will inform future outreach, technical assistance, and project development.

Technical assistance should focus enabling the transition to electric mobility within broader goals, including sustainable transport, energy security, domestic industrial development, and GHG abatement goals. The goal of scaling up domestic manufacturing is also being considered by many EMDE countries, such as South Africa, Mexico and Viet Nam.

WHAT MORE NEEDS TO BE DONE?

To further accelerate progress, countries should undertake more and better co-ordinated work to scale up financial and technical assistance for EMDEs, covering areas such as the supply of electromobility technologies and products, policy development and standards.

Countries working together in international forums can support this aim through actions such as identifying priority countries for technical and financial support, improving

awareness among EMDE countries about available support, addressing geographical[9] and thematic gaps, de-risking investments to mobilise the private sector, and promoting knowledge and technology sharing.

Countries should also work to better track project-level key performance indicators to guide future policies and assistance efforts, including for major financial donors, such as the Global Environment Facility (GEF) and multilateral development banks.[10] Towards this aim, countries and International Financial Institutions (IFIs) should task an agency or provide a platform to establish and maintain a publicly shared database documenting their financial assistance to EMDEs for electric mobility.

Providing enhanced, tailored in-country technical assistance will require an increase in dedicated funding linked to specific and measurable deliverables across the entire project cycle. This should include equipping recipient governments with the capability to develop and implement policy frameworks supporting ZEVs, as well as a clear plan for implementation, monitoring and reporting on the impact of policies or progress on projects across various levels (city, regional, national).

Countries should also identify mechanisms to reduce the cost of capital, leveraging various funding streams and strengthening international collaboration to address upfront costs, while ensuring that lender countries are aware of and can access low-cost finance. Lessons learned from India's experience in aggregating demand and procuring 5 500 e-buses could provide valuable insights in this regard.

Engagement between domestic companies across the full electric mobility supply chain (electricity generation, transmission and distribution; charging; OEMs; battery-related mining, processing, production and recycling) and lenders should also be promoted**,** collaborating with providers of technical assistance and low-cost finance to devise projects with widespread, mutual developmental benefits.

Assistance should also support development goals, including sustainable transport, energy security, domestic industrial development and GHG abatement goals.

RECOMMENDATION RT2 HAS BEEN UPDATED AS FOLLOWS:

Governments and international organisations should increase low-cost financing and dedicated funding to projects to accelerate ZEV adoption in EMDEs, focusing on ensuring that EMDE countries are aware of and have ready access to technical assistance and financing offers, and ensuring the effectiveness of project delivery and policy development support.

[9] In working group meetings of the ZEV-TC IAT, members have highlighted the need to expand geographical coverage of technical and financial assistance to countries in the Middle East, West Asia, Central and Eastern Europe, and Small Island Developing States (SIDS).

[10] Including the World Bank, ADB, African Development Bank, EBRD, InterAmerican Development Bank, and others.

AGREEMENT ON STANDARDS FOR THE SUSTAINABILITY OF BATTERY SUPPLY CHAINS

OVERVIEW

Last year, we recommended that governments should work together to agree harmonised standards to ensure sustainability and social responsibility along the EV battery supply chain. At COP 27, countries under the Road Transport Breakthrough agreed to accelerate work to improve the sustainability of ZEV battery supply chains globally, by working together to establish a mechanism for countries and businesses to share best practice and knowledge, support implementation and explore opportunities for harmonising standards by COP 28.

In April 2023, the Global Battery Alliance (GBA) formally agreed to lead co-ordination on ZEV battery supply chain sustainability. The GBA is a multi-stakeholder organisation focusing on the sustainability of battery value chains, with convening power across the public and private sectors, and, importantly, includes civil society stakeholders. Its 10 guiding principles for a sustainable and responsible battery value chain have been endorsed by over 130 businesses, governments, academics, industry actors, international and non-governmental organisations.

WHAT PROGRESS HAS BEEN MADE?

We assess that modest progress has been made against our recommendation from last year.

In 2022, GBA launched its Greenhouse Gas Rulebook, a set of rules for calculating and tracking the GHG footprint of lithium-ion batteries for EVs from mining to end of life and recycling. The first Battery Passport proof of concept was launched in January 2023, in parallel to child labour and human rights indices to support due diligence as part of the Battery Passport framework. Throughout 2023, the GBA has continued to develop the Battery Passport indicator framework, emphasising transparent, public and inclusive consultations on the GHG rulebook, and will continue piloting and hosting consultations on data governance. The GBA will also convene a member working group to delve deeper into key obstacles and levers to enhance circularity across battery value chains.

The GBA is joined in leading efforts to improve the sustainability of ZEV battery supply chains globally by the World Economic Forum's Circular Cars Initiative,[11] UNEP and the Environmental Collaboratory at Drexel University. Together, these groups aim to establish

[11] The Circular Cars Initiative (CCI) was launched in 2020 and co-hosted by World Economic Forum and WBCSD. It has engaged more than 60 companies and organisations, aiming to reduce lifecycle emission of vehicles manufacturing.

a mechanism for countries and businesses to share best practices and knowledge, to support implementation, and to explore opportunities for harmonising data standards by COP 28.

The GBA is drafting a communiqué for release at COP 28, with recommendations on priority actions to enhance the sustainability performance of battery value chains globally, including but not limited to harmonisation of standards across major markets such as Europe, the United States, China, Japan and India. Further, the GBA is scoping the potential for other initiatives to endorse these recommendations.

At the global level, the UNECE World Forum for Harmonization of Vehicle Regulation, which convenes governments representing more than 90% of global road vehicle production, has played an important role in creating standards for EV battery durability and convening governments to develop a globally harmonised methodology for emissions accounting covering the entire automotive life cycle (including not only batteries, but all vehicle components). The Working Party on Pollution and Energy (GRPE) has issued regulations on EV battery durability for light-duty vehicles (UN GTR No. 22), which were used both in Europe's Euro7 proposal and (with small changes) in the United States EPA regulations. The GRPE is now working on similar standards for medium- and heavy-duty vehicles.

Furthermore, in January 2023, the GRPE started regulatory work on automotive lifecycle assessment. This work, led by the governments of Japan and Korea, aims to develop an internationally harmonised procedure to determine the carbon footprint of vehicles, with priority topics including methods to account for the carbon footprint of EV battery production, reuse and recycling. There is increasing recognition that reaching net zero by 2050 will require more comprehensive regulations and ambitions with a wider scope, and that reduce emissions across the entire vehicle lifecycle.

While Europe[12] and China have been leading the way in regulations on EV battery production and end-of-life disposal, an important cross-regional collaboration between the European Battery Alliance[13] and Li-Bridge initiative[14] in the United States began in 2022, focusing on battery sustainability, recycling and reuse, environmental justice and other topics. Interest in establishing a consistent data basis and methodology for assessing the carbon intensity of EV battery production and end of life has also been expressed by governments including China, Japan, Korea and Sweden.

[12] Recognising the importance of lithium, nickel, and cobalt needs for future EV batteries, a provisional political agreement has been reached between the European Parliament and Council on a new Battery Regulation, which includes a set of provisions on material sourcing, recycled content, and emissions intensity for producing EV batteries.
[13] The European Battery Alliance was launched by the European Commission in 2017 to promote safer traffic, cleaner vehicles and sustainable technological solutions.
[14] The US Government launched Li-Bridge to develop a robust and secure domestic battery supply chain.

WHAT MORE NEEDS TO BE DONE?

As many governments develop policies to establish or grow domestic battery manufacturing supply chains, it will be critical for governments to work together to ensure that valuable battery materials are mined, processed and developed into EV battery cells and packs in a sustainable and just manner. This will be easier for the global industry to achieve if there is greater international consistency or convergence of methods, reporting frameworks, and, whenever possible, of regulation.

Currently it is not at all clear that regulatory standards being developed will meet minimum harmonisation and interoperability standards. An immediate opportunity, given that the battery passport ecosystem is evolving rapidly, is for countries to ensure common and interoperable standards for digital product passports, including battery carbon footprint, responsible sourcing and data governance. These are the minimum elements that would be needed to ensure that other considerations, such as the provenance and purity of minerals embedded in batteries, the identity of the companies and the labour conditions involved in each step of the supply chain, and other environmental impacts, can be accurately accounted for and tracked, such that regulations targeting each of these facets can be effective. Such common accounting and tracking methodologies can enable greater convergence in regulatory requirements, which governments should pursue in parallel.

International co-operation on the handling of used EV batteries at the end of their lifetime will also be important. Technical assistance can support developing countries to put in place effective policies for EV battery collection, storage, recycling and reuse, and other end-of-life opportunities. For government fleets, considering battery sustainability during the vehicle procurement stage can also improve battery circularity.

Finally, governments should jointly address key obstacles to enhanced sustainability and circularity in battery value chains, including harmonisation of policies on trade and (transboundary) transport of battery materials and recycling at the end of life.

RECOMMENDATION RT3 HAS BEEN UPDATED AS FOLLOWS:

Governments should work together to agree on harmonised sustainability standards and metrics, including battery carbon footprint, responsible sourcing and broader environmental, social and governance risks and impacts wherever possible. In the context of digital product passports, they should work towards enabling global interoperability, including harmonised data governance (i.e. data collection, management, assurance and verification standards). Further, governments should jointly address priority areas for sustainable value chains including transport, trade and recycling bottlenecks for battery materials at the end of life, circularity-based product design and processing, and technical assistance for developing markets and emerging economies on EV battery end-of-life management.

WORKING TOGETHER TO MOBILISE INVESTMENT IN CHARGING INFRASTRUCTURE

OVERVIEW

Last year, we recommended that countries should share best practice in policy to mobilise investment and accelerate the deployment of charging infrastructure. At COP 27, countries under the Road Transport Breakthrough agreed to accelerate the development and deployment of ZEV infrastructure globally by working together to establish a mechanism by the time of COP 28 for sharing best practices and supporting implementation by countries and businesses at national and regional levels.

The signatory countries nominated The International Council on Clean Transportation (ICCT) – through the work of the ZEV-TC and in partnership with CALSTART, the Green Grids Initiative (GGI), WBCSD, the Transport Decarbonisation Alliance (TDA), The Climate Group, EV100, and EVI – to lead in establishing a specialist knowledge and best practice sharing and co-ordination mechanism on ZEV infrastructure by COP 28. This is expected to include a long-term vision for meeting ZEV infrastructure needs and exploring the development of new standardised tools and products to support ZEV infrastructure planning and modelling at different levels.

Additionally, countries agreed to actively engage in ongoing international discussions alongside vehicle manufacturers on the alignment of charging types, and to invite ICCT to review progress on the development of international standards for vehicle charging types by COP 28.

WHAT PROGRESS HAS BEEN MADE?

We assess that modest progress has been made against our recommendation from last year.

In March 2023, the ZEV-TC launched a taskforce composed of participating governments, other organisations,[15] and private stakeholders such as automakers, energy network providers, and chargepoint operators, to discuss how best to facilitate charging infrastructure deployment. The taskforce will focus not only on the current deployment status and future needs,[16] but also best practices and strategies to address barriers.

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[15] Members include C40, TDA, Green Grids Initiative (GGI), EVI, CALSTART, and the Climate Group.

[16] For more data on developments in policy and deployment of ZEV infrastructure, see the IEA Global EV Outlook and Global EV Data Explorer, as well as the ZEV Transition Council data portal. More detailed assessments of charging deployment needs, other infrastructures that can enable, accelerate, and expand the operational feasibility of ZEVs have been undertaken on battery swapping (e.g. in the IEA (2023), Global EV Outlook), in an ITF assessment of the potential for systemic cost savings of Electric Road Systems, and on Hydrogen Refuelling stations deployment and innovation in the Global Hydrogen Review.
Detailed assessments of the charging infrastructure needs through 2030 have been developed by the ICCT, as well as in the Global EV Outlook. With regards to charging infrastructure in EMDEs, see the 2023 ICCT publication, EV charging infrastructure in EMDEs. On the heavy-duty side, a recent ICCT report focuses on depot and fast- and ultra-fast "mid-shift" charging and grid upgrade needs at the county level across the United States.

Participating governments have agreed to prioritise 1) the impact of EVs on the electricity grid, and 2) standards for charging infrastructure, user-friendliness and the importance of sharing data. The group has also agreed to develop by the end of 2024 a global roadmap to worldwide reliable public and private charging infrastructure.

The ZEVWISE Coalition[17] shares expertise on ZEV policies in the medium- and heavy-duty vehicle segments and addresses key issues on infrastructure deployment and financing. Its May 2023 meeting outlined relevant evidence (e.g. a recent ICCT report on the cost savings of smart charging to road freight operators), as well as strategic network planning to enable charging of electric road freight in the United Kingdom and United States.

In an initiative led by the Dutch Government, ZEVWISE partners drafted a call to transport ministries and other organisations that was circulated at the International Transport Forum's Transport Summit in May 2023, calling on energy ministries to more rapidly deploy charging solutions for EVs, with a particular focus on grid readiness needs for medium- and heavy-duty electric trucks and buses.

WHAT MORE NEEDS TO BE DONE?

Lack of sufficient charging infrastructure is likely to be a major factor constraining the pace of the transition to ZEVs in many countries. To avoid this, it will be important for governments to have access to high quality analysis and advice on policies to accelerate infrastructure deployment. Countries can improve the quality of international exchange of best practice by commissioning studies to identify the infrastructure policies that have so far proved most effective in mobilising private investment and expanding coverage.

Charging infrastructure should be a priority for international assistance to developing countries on the road transport transition (see previous section). This can be supported by countries and international organisations designing regional roadmaps that lay out the needs for coherent infrastructure deployment, especially considering the infrastructure needs for medium- and heavy-duty trucks and buses given the higher power needed to supply these vehicles.

RECOMMENDATION RT4 HAS BEEN UPDATED AS FOLLOWS:

Governments should agree to further increase technical and financial assistance to support charging infrastructure. Governments and companies should support and leverage the mechanisms established for sharing best practices, knowledge, and relevant technology, and for supporting implementation by countries and Non-State Actors at national and regional levels.

[17] ZEVWISE partners are the Government of the Netherlands, The US Department of Energy, UK Department for Energy Security and Net Zero, UNEP, International Transportation Forum, The ICCT, the World Bank, Smart Freight Centre, Clean Vehicle Initiative, The CEM Electric Vehicles Initiative, the WBCSD and CALSTART.

TAKING THE MOST POLLUTING VEHICLES OUT OF INTERNATIONAL TRADE

OVERVIEW

Last year, we recommended that vehicle importer and exporter countries should agree on harmonised regulations on vehicle standards to ensure vehicle efficiency and safety in internationally-traded used vehicles. At COP 27, countries under the Road Transport Breakthrough agreed to initiate a dialogue among a coalition of importer and exporter countries by COP 28, to develop harmonised quality standards for used ICE vehicles. Countries also committed to support the international trade of second-hand ZEVs and to publish future plans in this regard.

WHAT PROGRESS HAS BEEN MADE?

We assess that good progress has been made against our recommendation from last year.

UNEP in particular has led efforts to build a consensus between major vehicle exporting and importing regions and countries. UNEP organised the first African used vehicles importers meeting already in 2021, involving 27 African countries and relevant regional organisations (e.g. African Union Commission [AUC], East African Community [EAC], Economic Community of West African States [ECOWAS] and United Nations Economic Commission for Africa [UNECA]). The meeting emphasised the importance of applying a regional approach based on harmonised standards and a vehicle data sharing system. Minimum standards for imported vehicles have subsequently been adopted by groups of countries in East Africa (EAC) and West Africa (ECOWAS).

The Safer and Cleaner Used Vehicles for Africa project, led by UNEP and UNECE, provided training on the framework for inspection and monitoring of imported used vehicles for stakeholders from member states in ECOWAS and EAC. Some 22 sub-Saharan African countries (15 from ECOWAS and 7 from EAC) have adopted regionally harmonised Euro 4-equivalent vehicle emission standards and used vehicle emission limits. Progress has also been made for other regions, including Southern and Central Africa, Asia, and Latin America and the Caribbean.

As part of this project, the UNECE World Forum for Harmonization of Vehicle Regulations has created a dedicated working group on Safer and Cleaner Used and New Vehicles (SCUNV), which aims to develop a common framework for technical requirements of new and used vehicles as pertaining to their safety and environmental condition. SCUNV is co-chaired by South Africa, Kenya, Nigeria, the Netherlands and the United States.

As covered in last year's report, UNEP has been given a formal charter by the UN Environment Assembly (UNEA) to pursue policy-oriented data collection and research on used vehicle quality standards. Under this mandate, UNEP has continued to engage with UN member countries over 2023, focusing recently on vehicle exporting countries. They will hold their next meeting on this topic in October 2023, with representatives from the United States, European Union, Japan and Korea, among others, accounting for around

90% of total used vehicle exports, expected to participate. The aim is to build political consensus on harmonised vehicle quality standards and practices for used vehicle export by the next UNEA meeting in March 2024. The World Trade Organisation, as an international framework for negotiation and formalisation of trade agreement, may also be able to play an important role in forming a harmonised global standard.

UNECE, UNEP and the United Nations Road Safety Fund (UNRSF) have organised several meetings of vehicle exporters and importers (both separately and jointly), with the most recent joint exporters and importers meeting held in September 2022. Participating countries include some EAC member countries, including Rwanda and Kenya, as well as the Netherlands as a major exporter.

In 2022, the European Commission started the process of revising the End-of-Life Vehicle Regulation, and the proposal is currently open for public comment. It is expected that the new regulation will address issues related to the export of polluting vehicles.

Another sign of the growing recognition of the importance of used ICE and EV flows, and the regulatory environment under which these flows will evolve, is the proliferation of studies focusing on the topic that have been recently released or are underway.[18]

WHAT MORE NEEDS TO BE DONE?

To establish a harmonised framework and quality standards that effectively remove the most polluting vehicles from the global market, an agreement would need to be made at the international level, not only among major vehicle exporting countries and regions, but also at intermediate ports (e.g. in New Zealand, North Africa and the Middle East), involving importing countries and regions. Under such a framework, vehicles for export should be inspected and certified for roadworthiness and compliance with at least Euro 4/IV minimum emissions standards. As many importing countries lack the capacity or financial resources for proper vehicle inspection, exporting countries should also adopt regulatory frameworks to ensure used vehicles can be inspected against relevant vehicle quality regulations (e.g. pollutant emission performance standards) at the port of export.

Limited accessible data on the global trade of used vehicles remains the largest barrier to tracking trade flows, monitoring vehicle status, and implementing regulations. To support improved data availability, used second-hand vehicle exports should be better tracked, with data made accessible to exporting and importing countries. This would improve visibility of used vehicle trade flows, and would make it easier to ensure that all relevant regulations (e.g. roadworthiness, emissions standards, vehicle age, etc.) and taxation policies are being followed.

[18] These include studies from UNEP, UC Davis, UC Davis and UNEP, the ITF and WEF and Systemiq.

RECOMMENDATION RT5 HAS BEEN UPDATED AS FOLLOWS:

Exporting and importing countries should agree on minimum standards for cross-border trade of used vehicles. Countries should establish a publicly accessible database for tracking cross-border used vehicle trade. Governments and companies should develop strategies to define and legislate quality standards, enforced at ports of export and defined based on standards established by importing countries, for used Internal Combustion Engine (ICE) vehicles, as well as commitments to support the international trade of second-hand ZEVs, and publish plans by COP 28

RECOMMENDED REPORTS

We recommend the following reports for more detailed descriptions of the technologies for road transport sector decarbonisation and of the actions that countries and businesses can take individually.

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Decarbonizing Road Transport by 2050: Effective Policies to Accelerate the Transition to Zero-Emission Vehicles (ICCT, 2021)

Decarbonising road transport by 2050: Accelerating the Global Transition to Zero-Emission Vehicles (ICCT, 2021)

Renewable Energy Policies for Cities: Transport (IRENA, 2021)

Global EV Outlook 2023 (IEA, 2023)

Facilitating Decarbonisation in Emerging Economies Through Smart Charging (IEA, 2023)

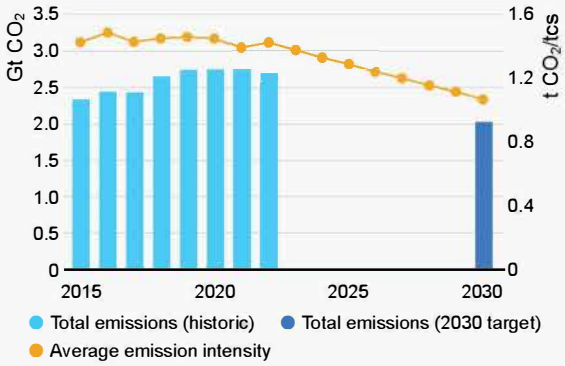
Accelerating ZEV adoption in fleets to decarbonize road transportation (ICCT, 2023)

Towards the Light: Effective Light Mobility Policies in Cities (ITF, 2023)

STEEL

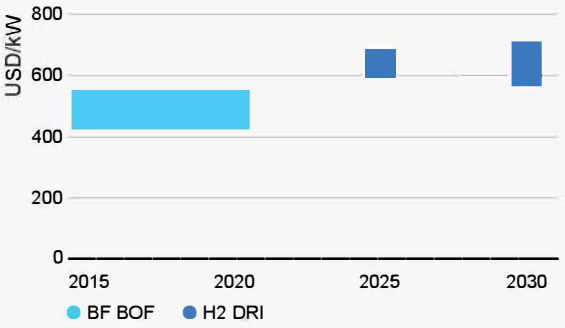
The steel sector is not on track to meet net zero by mid-century, with total emissions still rising and less than 1 Mt of near-zero emission steel currently being produced. A significant number of new high-emission blast furnaces are anticipated, with nearly 90 Mt either planned or underway before 2025. However, announcements for new near-zero emission steel projects are also increasing, more than doubling since last year.

Emissions[1]



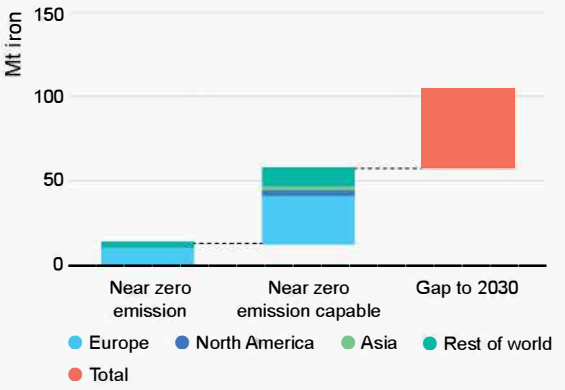
- Total CO_2 emissions from the steel sector have risen since 2015, before stabilising since 2019.
- Direct CO_2 emissions intensity has been broadly flat since 2015.
- Both need to fall by around 25% by 2030, or 3% each year, to get on track for net zero by mid-century.

Costs[2]



- The blast furnace-basic oxygen furnace (BF-BOF) route currently makes up 70% of global steel production, with an average cost of USD 490/t between 2015 and 2020.
- Hydrogen direct reduced iron (H2 DRI) is preferred by steelmakers in some regions as a low-emission alternative.
- Cost estimates for 100% hydrogen blend are around USD 650/t for the first commercial-scale plants in 2025; 25% more expensive than BF-BOF.

Deployment[3]



- The project pipeline for primary near-zero emission projects has increased to 13 Mt, from 5 Mt last year.
- For primary near-zero emission capable[4] plants, this has increased slightly to 58 Mt.
- Latest analysis suggests that over 100 Mt of near-zero emission ironmaking production is required by 2030, representing a gap of nearly 50 Mt, assuming all capable projects move to near-zero emissions in the near future.

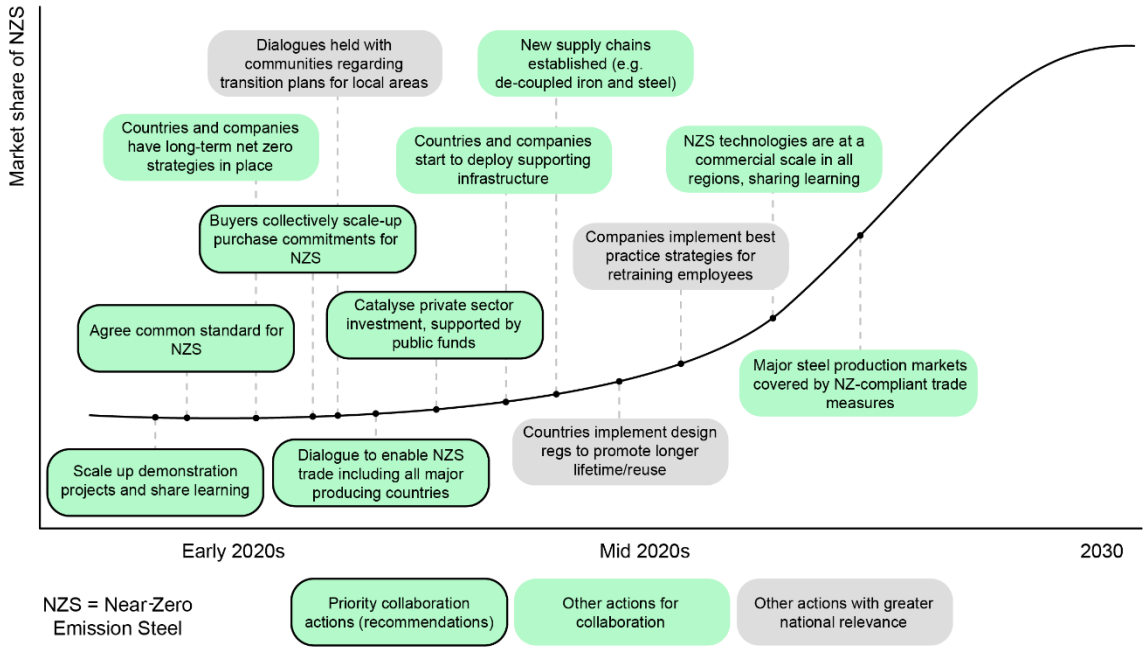
[1] Notes: LH axis = total emissions (bar); RH axis = emissions intensity (line). Source: IEA (2023), Tracking Clean Energy Progress: Steel.
[2] Levelised costs. Notes: tcs = tonne of crude steel. Sources: TransitionZero for historic blast furnace production costs, Mission Possible Partnership (MPP) for 2025 and 2030 100% H2 DRI costs. H2 prices assumed to be USD 1.6 – 2.5 in 2025 and USD 1.2 – 2.1 in 2030.
[3] Source: IEA (2023), Net Zero Emissions by 2050: A Roadmap for the Global Energy Sector – 2023 Update (forthcoming).
[4] "Near-zero emission" refers to projects that, once operational, will be near-zero emission from the start, as defined in the IEA report Achieving Net Zero Heavy Industry Sectors in G7 Members. "Near-zero emission capable" refers to projects that will achieve substantial emissions reductions from the start – but fall short of near-zero emissions initially – with plans to continue reducing emissions over time such that they could later achieve near-zero emission production without substantial additional capital investments in core process equipment.

STATE OF INTERNATIONAL COLLABORATION

In last year's report, we identified international collaboration in the areas of standards and certification, demand creation, research and innovation, trade and finance as being important to the transition in the steel sector, and made recommendations on the most urgent and high-impact opportunities in need of international collaboration in each of those areas. In this report we assess progress against those recommendations. Our assessment is summarised in the table below, and the following sections address each area of international collaboration in turn.

Area	What progress has been made?	What more needs to be done?	2023
Standards and certification	• Increase in membership of and co-ordination between key public and private sector initiatives. • Emerging consensus on emissions accounting methodologies. • Growing convergence on definitions for 'near-zero emission steel'.	• Achieve broad consensus on methodologies by end 2024. • Agree process for verifying 'near-zero emission' claims. • Accelerate adoption of standards in national policy through collaboration between countries.	Good
Demand creation	• Increase in membership of key public and private sector initiatives, with CEM IDDI growing from countries representing 9% to 20% of global steel production. • Increased efforts to engage regions outside Europe and North America.	• Move from commitments and pledges to contracts and policies. • Agree to share procurement data to strengthen demand signal.	Modest
Research and innovation	• Growing number of successful private sector collaboration models for steel. • Initial bilateral country partnerships being established under Mission Innovation NZIM.	• Scale up country-level collaboration, making best use of private sector models where possible. • Work closely with climate finance funds to build engagement with developing countries.	Modest
Trade conditions	• Some initial progress within new and existing forums and agreements, such as the WTO, OECD, Climate Club and GASSA.	• Establish a dialogue on steel decarbonisation policies and trade, involving all major steel producing and consuming countries.	Modest
Finance and investment	• Launch of new funds, such as CIF Industry (USD 80 million out of USD 500 million capitalised). • Initial interest to improve the effectiveness of delivery, including from LeadIT and the Climate Club.	• Establish a matchmaking platform to link supply and demand for assistance and build sectoral expertise among major IFIs. • Donor countries to further increase commitments for industry decarbonisation funds.	Modest

Figure 5.1. Critical path to 2030 for the steel sector



GREATER ALIGNMENT ON EMISSIONS ACCOUNTING METHODOLOGIES AND DEFINITIONS FOR NEAR-ZERO EMISSION STEEL

OVERVIEW

Last year, we recommended that countries should agree on common definitions for low and near-zero emission steel, along with a timeline for the adoption[1] of standards by the mid-2020s. A significant step towards achieving this recommendation was made at COP 27, where countries under the Steel Breakthrough agreed to develop a common timeframe for the adoption of standards by COP 28. They identified the Clean Energy Ministerial (CEM)'s Industrial Deep Decarbonisation Initiative (IDDI) and ResponsibleSteel as primary platforms to carry forward this work, although several other organisations are increasingly active in this space, including the International Organization for Standardization (ISO) and the World Trade Organization (WTO).

[1] Adoption refers to the requirement for companies to meet such standards in certain government policies, such as procurement, access to finance, subsidy, or regulations.

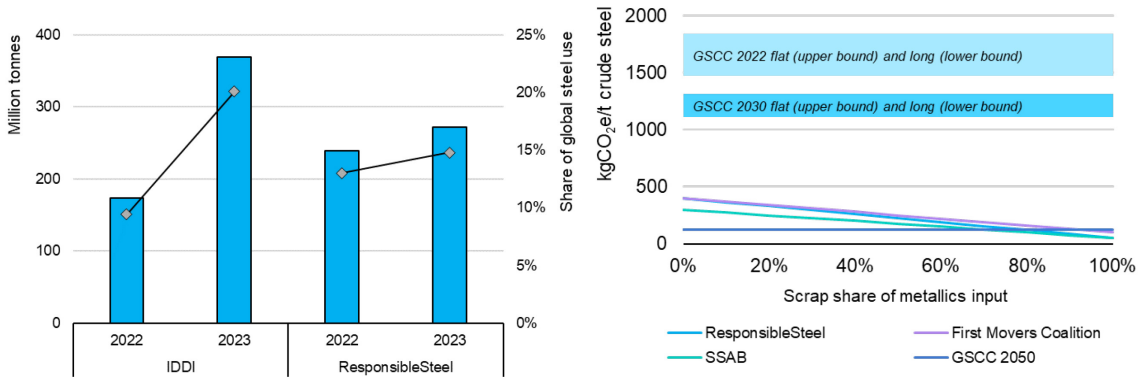
WHAT PROGRESS HAS BEEN MADE?

Overall, we assess that good progress has been made against our recommendation on the common understanding of definitions and standards.

Since 2022, IDDI has increased its membership from 5 to 10 member countries, increasing their coverage as a share of global steel production from 9% to 20%. This now includes India, Japan, the United States, Germany, Brazil, Canada, Saudi Arabia, the United Kingdom, Sweden and the United Arab Emirates (in order of steel production). IDDI plans to trial Product Category Rules for steel and cement used in construction with several of their member countries this year, with Germany, the United Kingdom and Canada consulting on low and near-zero emission standards in 2023, in part informed by the IEA work under the G7 during 2022. They are also developing guidance to support the harmonisation of emission accounting methodologies used in different regions for finished steel products.

ResponsibleSteel membership has increased from 133 to 148 companies (all of which are required to set a 1.5 °C aligned net zero goal), now totalling 272 Mt, or around 15% of global steel production, with 58 sites achieving certification. They are currently testing V2.0 of their international standard and will launch V2.1 in Q4 2023, with the potential for further revisions in 2024.

Figure 5.2. Coverage of initiatives and emission threshold proposals



Notes: GSCC = Global Steel Climate Council. IDDI = Industrial Deep Decarbonisation Initiative.

Membership of key initiatives is growing and there is some level of convergence on emission thresholds to define near-zero emission steel.

There are two main components to the development of steel standards: an emissions accounting methodology, and normative thresholds that define low-emission steel. On the former, there has been encouraging progress, with the G7 Presidency of Japan commissioning the IEA to carry out a report on emissions accounting methodologies, which was endorsed by the G7 in the Leaders' Communique and will be taken forward by a larger group of countries within the IEA's new Working Party on Industrial Decarbonisation

(WPID). This will aim to align the various approaches used by ISO, worldsteel and ResponsibleSteel, with a high degree of interoperability looking possible in the next couple of years.

There is also work under development to improve the reporting and verification of methane emissions in the steel supply chain, which accounts for around a third of the total GHGs from steel production. To address this challenge, the United Nations Environment Programme (UNEP) is developing a Steel Methane Partnership, an initiative aimed at lowering methane emissions from metallurgical coal production by 60-75% by 2030. The Partnership includes a detailed performance, reporting and verification framework on methane from metallurgical coal production, representing an opportunity for collaboration with the other organisations and initiatives developing similar guidance for other parts of the supply chain.

With regards to definitions for low and near-zero emission steel, there has been notable progress towards some convergence, including between ResponsibleSteel, First Movers Coalition, WV Stahl, IDDI and SSAB. An alternative has been proposed by the Global Steel Climate Council (GSCC) based on an emissions threshold that stays constant as the share of scrap input changes. Several companies have also begun work to label and brand products based on these definitions. This includes the world's largest steel company by production, China's Baosteel, which has developed its own standard to market lower emissions steel. Their "Beyond ECO" standard certifies steel at 30% lower emissions than a 2020 baseline, with more ambitious thresholds expected to be set in future.

The Global Arrangement on Sustainable Steel and Aluminium (GASSA) between the United States and the European Union aims to deliver an agreed approach to emissions accounting by October 2023, although whether or not this would choose to also adopt existing proposals covered above at a later stage is unclear. The Climate Club, launched in December 2022, also aims to work with its members on definitions and accounting methodologies, providing a potential political forum to build support, expanding on existing technical work. While a degree of alignment will be required, complete agreement between organisations is unlikely and perhaps not necessary at this stage. Rather, an independent assessment of different standards of compatibility with a net zero steel sector may be required, similar to the work of the UN High-Level Expert Group on the Net Zero Commitments of Non-State Entities, to avoid conflicting or confusing claims. This is further explored in the cross-cutting section of this report.

WHAT MORE NEEDS TO BE DONE?

The priority now is for governments to establish a clear timeline for the alignment of emissions accounting methodologies, followed by the use of low and near-zero emission definitions in policies. Germany, the United Kingdom and Canada are likely to lead the way, with consultations underway in 2023, as well as the potential outcome of GASSA. Much greater support for sharing best practices from this early cohort will be needed to facilitate uptake in all major steel producing countries. This should include countries working together to progress the technical alignment of methodologies, including through forums

such as IDDI, the IEA's WPID and those under the WTO, tied together with technical and financial assistance. Countries should then work together to support the implementation of low and near-zero emission standards by the mid-2020s, learning from the experience of first-mover countries.

> RECOMMENDATION S1 HAS BEEN UPDATED AS FOLLOWS:
>
> Governments and companies should work through existing collaborative forums to align emissions accounting methodologies for steel by the end of 2024. Countries representing the majority of global steel production should commit to adopting net zero compatible mandatory standards from the mid-2020s. Appropriate steps should be taken to clarify the compatibility of emerging definitions with net zero.

FURTHER SCALE-UP OF HIGH-QUALITY COMMITMENTS TO PURCHASE NEAR-ZERO EMISSION STEEL

OVERVIEW

Last year, we recommended that governments and companies should increase the scale of high-quality near-zero emission steel procurement commitments. At COP 27, countries under the Steel Breakthrough agreed to rapidly scale up demand commitments for low and near-zero emission steel by co-ordinating public and private purchase agreements. These countries identified IDDI, the First Movers Coalition[2] (FMC) and SteelZero[3] as leading initiatives in this area.

WHAT PROGRESS HAS BEEN MADE?

We assess that there has been modest progress against our recommendation, with some increases in demand-side commitments, although in many cases these have been insufficient to bring forward major new investments.

Membership has grown across all three initiatives, with IDDI growing from 5 to 9 members (see above) and FMC and SteelZero increasing the number of companies by 5 and 13 since the end of 2021, respectively. Beyond these initiatives, an additional 19

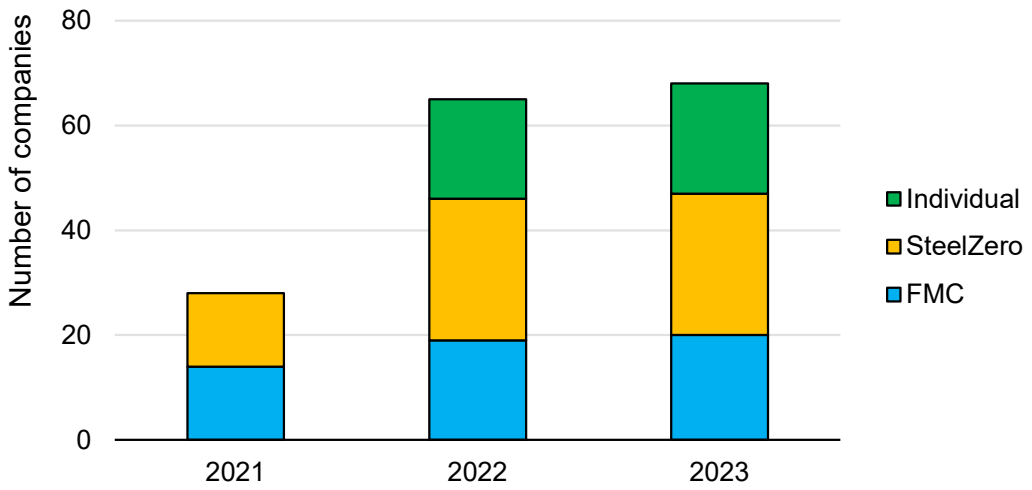
[2] First Movers Coalition Steel commitment (2022).
[3] SteelZero and the SteelZero Commitment Framework.

companies have made commitments, often via direct offtake agreements with a producer. Membership is still highly regionally focused, with 88% of private sector commitments being from companies headquartered in Europe.

To support outreach in other regions, FMC is holding in-country workshops in India, Brazil, the United States and the United Arab Emirates, and SteelZero launched in India in 2022, with activity growing in the United States, Korea and Japan, although in both cases these are yet to translate into new commitments from companies based in these countries. Involvement of major steel companies in China has not yet been possible, although Baosteel – whose annual production is similar to that of India, the second largest country by steel production – has finalised an agreement with Mercedes-Benz to supply low-emission steel (at 30% lower emissions than baseline), suggesting that activity is also beginning there.

At COP 27, IDDI launched a four-tier Green Public Procurement pledge, and – as of 2023 – members are still considering their proposed level of commitment. IDDI published a progress report in early 2023 on their work and future plans. Via public procurement, IDDI members have direct influence over approximately 5% of global steel demand, representing major potential to support an early market for low and near-zero emission steel. By working together, IDDI members can send a much stronger international signal than they would be able to send on their own. It will be important for member countries to commit to the highest ambition for using near-zero emission steel in the majority of public projects by 2030, helping to bring forward investment decisions for major steel producers.

Figure 5.3. Number of companies committed to purchase low-emission steel



Notes: FMC = First Movers Coalition. Figures as of August 2023.

The number of companies committing to purchase low-emission steel has more than doubled since the end of 2021, although the vast majority of buyers are located in Europe.

WHAT MORE NEEDS TO BE DONE?

As recommended last year, to support investment in near-zero emission steel production, steel companies will need legally enforceable, multi-year commitments from buyers, supported by robust standards (as covered above). Initiatives are yet to translate a notable portion of early-stage announcements into pledges that can support investment decisions by steel producers, although leading examples of more formalised commitments, such as the UK policy consultation, Canada's Greening Government Strategy, and private sector commitments to purchase near-zero emission products with a green premium, such as those from H2 Green Steel in Sweden, are starting to emerge.

It is also important for participation in demand-creation initiatives, such as IDDI, to continue to expand, as coverage of a larger share of the global steel market could greatly increase the effectiveness of these efforts.

Due to the commercial sensitivity and early stage of some of these commitments, it has not been possible to estimate the level of steel demand that is covered. There are early attempts by some of the initiatives mentioned above, as well as by some steel industry data providers. Greater transparency on procurement data can help strengthen the demand signal for potential low-emission steel producers. Governments and companies should agree to share aggregated anonymised data with relevant initiatives, which in turn can help catalyse investment in new facilities and identify gaps.

RECOMMENDATION S2 HAS BEEN RESTATED AS FOLLOWS:

> Governments and companies should increase the scale of near-zero emission steel procurement commitments to cover a significant share of their future steel demand, joining relevant public and private sector initiatives where these commitments are aggregated. These commitments should be high quality and should be supported by appropriate legal and implementation frameworks, such as advance purchase commitments

STRONGER COLLABORATION ON DEVELOPMENT AND DEMONSTRATION, MAKING USE OF SUCCESSFUL CO-OPERATIVE MODELS

OVERVIEW

Last year, we recommended that governments and companies should identify several commercial-scale pilot projects, in all major steel producing regions, where international collaboration can support shared learning. At COP 27, countries under the Steel Breakthrough agreed to collaborate internationally to identify a growing number of globally significant priority demonstration projects and share learning from them. Countries identified the Mission Innovation Net Zero Industries Mission (NZIM) to take this forward, with support from the Mission Possible Partnership (MPP).

WHAT PROGRESS HAS BEEN MADE?

We assess that there has been modest progress against our recommendation on research and innovation collaboration in the steel sector.

In September 2022, the NZIM was launched, co-led by Australia and Austria, with membership from Canada, China, the European Commission, Finland, Germany, Korea, the United Kingdom and the United States. In March 2023, members of NZIM set out an action plan which aims to establish a stakeholder dialogue, design and implement frameworks for co-ordinating and accelerating global co-operation, and leverage existing work. NZIM aims to strengthen ties with the private sector, particularly technology suppliers and energy-intensive industry. NZIM is yet to co-ordinate activities with MPP, although this could be one useful forum to access leading private companies and a pipeline of initial projects to share learning from.

There are still some significant innovation challenges to be overcome in order to support the rapid scale-up and cost reduction of low-emission steel production. This includes achieving the first commercial-scale operation of a hydrogen direct reduction furnace, overcoming the limited supply of high-quality iron ore (currently important for the hydrogen direct reduction to electric arc furnace route), increasing the scale of zero carbon electricity available (both for direct electrification and hydrogen-based processes), ensuring efficient material use and reuse in various end-use sectors, and enabling the cost-effective supply and storage of renewable and low-carbon hydrogen.

In order to overcome these challenges at a pace compatible with a net zero trajectory, multiple projects trialling different approaches in parallel are required across both developed and developing countries. Formal knowledge-sharing platforms such as NZIM, as well as private sector collaborations, are needed to accelerate collective learning.

Examples of private sector knowledge-sharing include the Hydrogen Iron & Steel Making Forum 2022, hosted by Swedish company SSAB and Korean company Posco. worldsteel also hosted its first Open Forum in September 2022, with a focus on breakthrough technologies. There are also a growing number of bilateral agreements between companies to trial new approaches in different geographies, including H2 Green Steel with Anglo American in South Africa and Brazil. New technology companies are also rapidly expanding into new geographies using subsidiary models. This includes Boston Metal, a company that has developed an approach to electrify the entire steelmaking process and launched a subsidiary in Brazil, with operation of a demonstration-scale plant due to start in 2023.

WHAT MORE NEEDS TO BE DONE?

To accelerate progress, countries should look to replicate and expand successful private sector-led models of technology collaboration and knowledge-sharing, as well as continuing to strengthen processes for shared learning through formal government-to-government initiatives. To enable greater private sector collaboration across borders, governments should facilitate major international opportunities for companies to share learning on these topics, with all parties agreeing on clear guidance on the opportunities and limits of information-sharing (i.e. a greater focus on the organisational and process-related challenges of establishing demonstration projects). Funds earmarked for financial and technical assistance can support developing country involvement in such collaborations, where direct financial support of projects is a challenge.

> RECOMMENDATION S3 HAS BEEN UPDATED AS FOLLOWS:
>
> Governments and companies should collaborate via existing initiatives to fast-track sharing of technology learning, business case development and policy support to accelerate the development of pilot projects. Emerging markets and developing countries' participation in key RD&D initiatives should be increased in support of this aim.

ALL MAJOR STEEL PRODUCING COUNTRIES TO ENGAGE IN OPEN AND INCLUSIVE DIALOGUES ON TRADE AND NEAR-ZERO EMISSION STEEL

OVERVIEW

Last year, we recommended that countries should urgently launch a strategic dialogue on trade to agree on ways to ensure near-zero emission steel can compete in international markets. At COP 27, countries under the Steel Breakthrough agreed to launch such a strategic dialogue on the trade of low and near-zero emission steel by COP 28. The Group of 20 (G20), the WTO and the OECD Steel Committee were identified by these countries as potential forums to convene countries to discuss these topics.

WHAT PROGRESS HAS BEEN MADE?

We assess that there has been modest progress against our recommendation on trade and the steel transition, with activity both among the nominated initiatives and organisations, as well as under new collaborative forums.

The G20 has yet to attempt discussions or agreements on the trade of near-zero emission industrial materials. However, in 2023 the Indian G20 Presidency took a small step in this direction by commissioning a report on circularity in the steel sector from IRENA. The analysis highlighted the importance of scrap in achieving a net zero steel sector, encouraging a freer flow of scrap steel around the world so that it can be used where it delivers the highest economic value and reduced emissions from the sector.

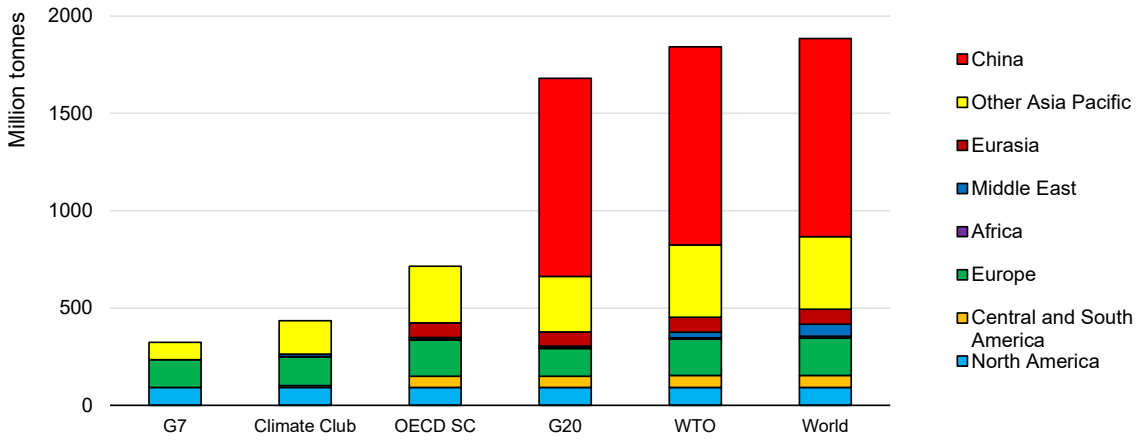
While no significant outcome is expected on steel trade in the G20 this year, progress to date indicates an initial attempt to put industry decarbonisation on the agenda at the G20 and reflects the challenge of reaching agreement, even on a less contentious issue.

Since COP 27, the WTO has undertaken new activity on steel sector decarbonisation, including publishing an information note on steel standards in December 2022 and hosting a Trade Forum on steel in March 2023, which brought together representatives from major markets to discuss how the WTO can help reduce potential trade fragmentation in the sector. Other relevant discussions are continuing under the Trade and Environmental Sustainability Structure Discussions (TESSD), the Technical Barriers to Trade (TBT) Committee and the Committee on Trade and Environment (CTE). While this was an important step forward for a more inclusive dialogue on trade and the steel sector's transition, such events do not yet represent the level of strategic dialogue recommended in last year's report.

The OECD Steel Committee has continued its work to support its member countries with analysis of major trends in the global steel industry, with a growing focus on decarbonisation. This has included work to assess the state of decarbonisation in the steel sector and a report for the G7 on the heterogeneity of steel decarbonisation pathways.

Similar to the WTO discussions, the membership of this Committee does not include all major producers, with notable absence of senior government representation from China.

Figure 5.4. Steel production by groups of countries by region



Notes: WTO = World Trade Organization. OECD Steel Committee (OECD SC) includes both full member countries and "participant" countries. Climate Club membership is accurate as of August 2023 but is likely to change.

Most recent intergovernmental collaboration on steel decarbonisation has occurred among the G7 but the vast majority of steel production is outside this group.

The GASSA represents the first potential joint agreement on steel decarbonisation, with an agreement between the United States and the European Union targeted for October 2023. Such an agreement is likely to focus on a joint methodology for assessing emissions from the steel sector, which can better inform future agreements in which trade terms could be linked to emissions standards. This is currently only a bilateral agreement, although there may be potential to extend it to a broader set of countries, depending on the negotiated outcome.

The European Union has also continued making progress on the implementation of its Carbon Border Adjustment Mechanism (CBAM), with a transition period starting on the 1st of October 2023, running until the end of 2025. From 2026, the CBAM will come into effect, requiring steelmakers to purchase certificates and report on their emissions. During the transition period, companies will be required to undertake quarterly reporting of embedded emissions in the products covered by the CBAM, which includes iron and steel.

One of the more significant new collaborative efforts in this area is the Climate Club, initiated by the German G7 Presidency, with Terms of Reference agreed among the G7 in December 2022. Since then, the Climate Club has expanded to 27 member governments[4] (as of August 2023), representing 23% of global steel production, co-chaired by Germany

[4] Australia, Austria, Argentina, Canada, Chile, Colombia, Costa Rica, Egypt, European Commission, Denmark, France, Germany, Indonesia, Italy, Japan, Kenya, Korea, Luxembourg, Morocco, the Netherlands, Norway, Singapore, Switzerland, Ukraine, the United Kingdom, the United States, Uruguay (as of August 2023).

and Chile and supported by the IEA and OECD as an interim secretariat. With the stated intention of being an inclusive, collaborative forum, the Club has sought to build a dialogue between developed and developing countries, illustrated by its current membership (approximately 30% of members are developing or emerging countries). While the activities of the Climate Club are likely to cut across several of the areas in this chapter, its initial aim was to raise collective ambition on industry decarbonisation and in so doing, to ease potential trade tensions.

WHAT MORE NEEDS TO BE DONE?

Strengthening the dialogue between major steel producing and consuming countries, including current major producers, and likely future major producers via open and inclusive forums will be vital to ensure that trading arrangements are conducive to the transition in the steel sector. Countries can help to build trust by providing clear communication of planned policy approaches to support steel decarbonisation (such as carbon contracts for difference), as well as collaborating on measures to enable the transition, such as emissions reporting, accounting methodologies and standards. In doing so, governments should be able to establish a shared understanding of equivalent measures between countries, whether these be price or non-price measures, while also making progress on key enabling conditions for the transition. Open communication between countries in these areas can support governments looking to adopt similar policies domestically, providing opportunities to learn from prior experience, as well as helping to avoid overly restrictive requirements for trade.

To support developing countries in establishing policies to accelerate the transition, developed countries should be proactive in providing an improved technical and financial support offer (covered in more detail in the next section), which can support key enabling conditions for trade, including administrative systems for emissions monitoring, reporting and verification.

RECOMMENDATION S4 HAS BEEN RESTATED AS FOLLOWS:

> Governments should urgently launch a strategic dialogue on trade and the steel sector's transition, including the leading producer and consumer countries, with the purpose of agreeing ways to ensure near-zero emission steel can compete in international markets.

IMPROVING THE EFFECTIVENESS OF TECHNICAL AND FINANCIAL ASSISTANCE FOR INDUSTRY DECARBONISATION PROJECTS

OVERVIEW

Last year, we recommended that developed countries and multilateral development banks should significantly increase funds for supporting the steel industry transition to near-zero emission technologies in emerging and developing countries. At COP 27, countries under the Steel Breakthrough agreed to enhance the overall public offer of international assistance in support of deep decarbonisation of the steel sector, which in turn would help mobilise private sector investment. The Leadership Group for Industry Transition (LeadIT) was nominated to take forward this work, building on the principles established by the Taskforce on Access to Climate Finance.

WHAT PROGRESS HAS BEEN MADE?

We assess that modest progress has been made against our recommendation on financial and technical assistance since last year, with some new funds being made available, although there is a lack of clarity for developing countries on the overall offer.

Since COP 27, LeadIT has been active in developing supporting evidence for this activity, including continuing in-country support with key partner countries and developing plans for a platform to help facilitate an enhanced technical and financial offer. This includes the mapping of International Financial Institutions' (IFIs) activities in support of steel decarbonisation, an ongoing project to understand the current technical assistance offer, and work within South Africa to support initial road-mapping.

Of 13 major IFIs, only 4 have relatively well-established programmes or projects that support steel decarbonisation: the International Finance Corporation (IFC), the European Bank for Reconstruction and Development (EBRD), the World Bank and the Climate Investment Funds (CIF). Notably, the CIF Industry Decarbonization Program was announced at COP 27, with an initial outlay of USD 80 million (out of a target of USD 500 million), although a timeline for supporting initial projects is yet to be finalised. Many of the existing programmes focus more heavily on energy efficiency and incremental emission reductions, given the limited availability and understanding of deep decarbonisation technology.

As more money is mobilised to support early efforts, greater focus will be required on the successful delivery of projects, in line with developing country needs. Given IFIs and supporting partners have relatively little experience in delivering steel decarbonisation projects, rapid learning among institutions around early successful case studies will be vital. Moreover, given that industry decarbonisation is often an emerging area of focus, there are very few examples of detailed project proposals that can attract IFIs' investment in recipient countries.

WHAT MORE NEEDS TO BE DONE?

One option to support the effective delivery of projects for steel (and indeed wider industry) decarbonisation would be a scaled-up matchmaking function, for both individual projects and wider policy-making, between donor countries, recipient countries, IFIs, national development banks, philanthropic organisations, private financial institutions and companies. Such a function should make use of existing case studies on implementing best-practice support programmes, such as efforts undertaken by the OECD Clean Energy Finance and Investment Mobilisation (CEFIM) programme and United Nations Industrial Development Organization (UNIDO). It should also work closely with existing routes for requesting and providing technical assistance, such as the NDC Partnership, avoiding duplication but rather focusing on improving the co-ordinated response.

A dedicated industry decarbonisation-focused platform could provide additional benefits beyond what already exists, allowing a closer community of practice to be established among the attending stakeholders, which is more challenging when financial and technical assistance cuts across multiple sectors. Regular meetings of political leaders (such as energy or industry ministers) at this platform can be helpful to bring greater focus to country requests and expedite progress in line with country ambitions.

As leading policy and industrial actors increasingly focus on deploying near-zero emission steel production facilities, it will be important for financial and technical assistance to support developing countries to participate in this market, not merely to produce high-emission steel with greater efficiency.

> RECOMMENDATION S5 HAS BEEN UPDATED AS FOLLOWS:
>
> Countries should establish an improved matchmaking function focused on industry decarbonisation and including steel that can better respond to developing country requests for financial and technical assistance. This should include donor countries, recipient countries, IFIs, national development banks, philanthropic organisations, private financial institutions and companies, with regular meeting of ministers.

RECOMMENDED REPORTS

We recommend the following reports for more detailed descriptions of the technologies for steel sector decarbonisation and of the actions that countries and businesses can take individually.

Iron and Steel Technology Roadmap (IEA, 2020)

Reaching Zero with Renewables: Eliminating CO_2 emissions from industry and transport in line with the 1.5ºC climate goal (IRENA, 2020)

Net Zero Steel Sector Transition Strategy (MPP, 2021)

Net Zero Steel project (IDDRI, 2021)

1.5°C Steel: decarbonising the steel sector in Paris-compatible pathways (E3G & PNNL, 2021)

Global Steel at a Crossroads (Agora, 2021)

Achieving Net Zero Heavy Industry Sectors in G7 Members (IEA, 2022)

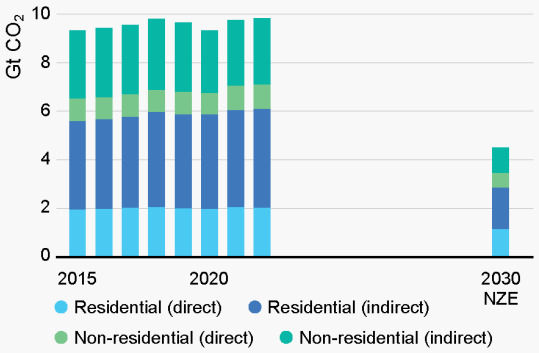
Emissions Measurement and Data Collection for a Net Zero Steel Industry (IEA, 2023)

Towards a Circular Steel Industry (IRENA, 2023)

BUILDINGS

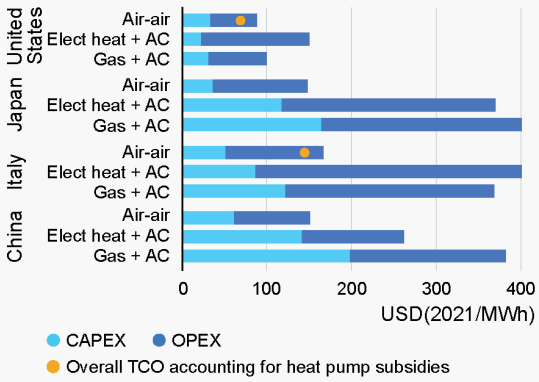
The buildings sector is not on track for net zero by mid-century, with emissions growing at an average of 1% per year since 2015. Global growth in floor area is more than offsetting the increased efficiency and decarbonisation efforts, where the long lifespan of buildings risks "locking in" vulnerable and high emission infrastructure. A major shift is required to decarbonise the sector while also ensuring it delivers resilience for communities.

Emissions[1]



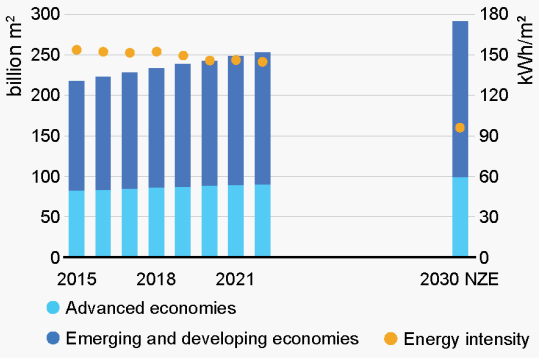
- In 2022, buildings sector emissions represent around a third of total energy system emissions, including buildings operations (26%) and embodied emissions (7%) associated with the production of materials[2] used for their construction.
- Operational emissions need to fall by about 50% from their 2022 level by 2030, to get on track with the IEA Net Zero Emissions Scenario (NZE Scenario). Embodied emissions also need to fall by 25% for steel and 20% for cement by 2030.

Costs[3]



- There are many aspects to near-zero emission and resilient buildings, including appliances (for heating and cooling) and materials.
- In most markets, low carbon appliances, such as heat pumps, entail higher upfront costs than conventional fossil fuel heating equipment but benefit from lower running costs over their lifetime due to their much higher energy efficiency.

Deployment[4]



- Total buildings sector floor area is set to continue increasing, with about 80% of the growth through 2030 taking place in emerging and developing economies.
- To achieve net zero by 2050, all new buildings need to be net zero from 2030, up from less than 5% of new buildings today.
- The final energy intensity of the sector has decreased by around 6% since 2015, although this improvement has been outpaced by floor area growth. Energy intensity needs to fall a further 35% by 2030 to be aligned with the IEA NZE Scenario.

[1] Global emissions from the buildings sector (operational phase) in the IEA Net Zero Emissions by 2050 Scenario, 2010-2030. Notes: NZE = Net Zero Emissions by 2050 Scenario. Source: IEA (2023), Tracking Clean Energy Progress 2023.
[2] Including cement, steel and aluminium in this accounting.
[3] Source: IEA (2022), The Future of Heat Pumps.
[4] Final energy intensity of total floor area. Source: IEA (2023), Tracking Clean Energy Progress 2023.

HOW DO WE GET THERE?

To get on track to meet the goals of the Paris Agreement, the buildings sector needs to meet two interdependent objectives:

- **Resilience**: anticipating, adapting and responding to climate shocks; and
- **Near-zero (emission)**: addressing both embodied and operational emissions[1].
- Near-zero emission buildings must be considered in the context of their whole-life impact, and for the enabling role they play in supporting the energy transition. Beyond their roles in reducing emissions, buildings are critical for delivering resilience to communities. Failure to embed resilience and adaptation measures into buildings will hinder efforts to decarbonise, as built assets will require more investment to maintain, repair and upgrade in response to physical climate risks and resulting changes in behaviour, thus also creating more emissions.

Delivering near-zero emission and resilient buildings involves all activities of the buildings and construction sector, from defining the requirements (regulation, policy, voluntary certificates), design (technical and spatial), product selection and execution, through construction, operation, maintenance and end of life.

Given that buildings have a long lifespan, early action is needed to avoid "locking in" vulnerability and emission pathways that could result from non-resilient and inefficient building design. Key to this is the building envelope, which plays a pivotal role in the long-term energy efficiency, durability and resilience of buildings. However, design considerations often face the challenge of narrow profit margins for designers, leading to the reuse of well-known systems rather than dedicated solutions adapted to the context.

The buildings and construction sectors encompass diverse technical expertise and skills, which may differ depending on the types of buildings[2] concerned and the contexts in different countries. Ensuring that the design and building phases are coherent is crucial and requires strong leadership and co-ordination.

A vision and milestones for the sector's transition are set out in the UN Climate Action Pathway and 2030 Breakthroughs, which require the sector to halve its emissions by 2030 (relative to 2021), with 100% of new buildings having net zero operating emissions by 2030, and widespread deep renovations of existing assets well underway. Embodied carbon must be reduced by at least 40%, with leading projects achieving at least 50% reductions.

[1] The buildings sector currently uses varied terminology to refer to buildings whose whole-life emissions are aligned with meeting the ambition of the Paris Agreement, including "near zero", "net zero" and "zero-carbon-ready", among others. In this Report, we refer to all Paris Agreement-aligned buildings as "near zero emission", in line with the proposed Buildings Breakthrough statement.
[2] According to UN Central Products Classification 5211-12, comprising 9 categories.

This vision is also aligned with the pathway for buildings in the IEA's NZE Scenario, in which all new buildings and deep renovations[3] are zero-carbon-ready[4] from 2030, new fossil fuel boilers are banned by 2025, and most appliances and air conditioning equipment are best-in-class by 2035, among other milestones.

Given the fragmented and siloed nature of the global buildings and construction sector, these aligned visions have a critical role in establishing a common shared pathway for all actors in the sector – from manufacturing and construction, real estate and finance, to end users and occupiers.

Achieving a near-zero emission and resilient building stock will require internationally co-ordinated policy actions to be delivered urgently, with the engagement of all stakeholders in the value chain.

Credible, implementable and ambitious roadmaps to define a pathway to near-zero emission and resilient buildings by 2030 should be developed and co-ordinated by national and sub-national authorities. To be effective, roadmaps must be developed through a collaborative process that focuses on priority actions and responsible agents. Roadmaps can support co-ordination across stakeholders, and send a long-term signal to the market around a common direction and pace of transition, including clear milestones for policy and regulatory measures for new buildings and renovations. Such a roadmap should also provide guidelines and deployment targets for technologies and infrastructure solutions that are compatible with a pathway to near-zero emission and resilient buildings, as well as develop the capacity of the industry to better assess and design for climate risks. In particular, it should prioritise action in those communities most vulnerable to a changing climate, with a focus on critical buildings (e.g. health care, education and infrastructure buildings). A platform to track and review progress against the roadmap targets will be vital to ensure accountability.

The development, strengthening and implementation of building energy codes[5], design standards and building performance certificates is an urgent need. This should include ensuring minimum performance standards for energy efficiency and resilience (e.g. structural improvements, habitability, climate adaptation), and limiting both operational and embodied emissions. Where countries already have codes in place, upgrades are needed to align with definitions for near-zero emission and resilient buildings, followed by a progressive expansion of such codes to major buildings renovations. The certification of buildings compatible with this definition also needs strengthening. Today, a range of certifications, mostly private, are in place in different regions and assessing their compatibility with near-zero emission and resilience is critical. Sub-national governments

[3] In this report we use "deep renovation" to mean the deepest reductions of energy consumption of a building, with improvements mainly concerning the building envelope and thermal energy systems.
[4] "Zero-carbon-ready" buildings are highly energy-efficient and resilient buildings that either use renewable energy directly or rely on a source of energy supply that can be fully decarbonised – such as electricity or district energy. Zero-carbon-ready buildings include both operational and embodied emissions in their scope.
[5] In this report, the term building energy codes is used beyond its current coverage, and also refers to the progressive shift of codes to cover whole life carbon as well as resiliency metrics, beyond energy performances. In some countries they are also called "building energy standards" and in this report the two terms are used interchangeably.

provide a platform to test, develop and lead deployment to provide future visibility and competencies around adoption of stricter building codes.

Harmonising and mandating whole-life carbon (WLC) assessments for new building projects and major renovations is critical to developing and normalising the necessary skills and knowledge across the value chain. Such assessments should be underpinned by harmonised (or interoperable) methodologies for assessing emissions across the lifetime of a building, such that data are comparable across projects. Data collected via these assessments is currently extremely limited and platforms are required to facilitate sharing and alignment to support project benchmarking and future decision-making. Interoperability and transparency of data should unlock international knowledge sharing capacity, thereby minimising the administrative burden on government and industry, particularly for emerging and developing countries.

The development of standardised frameworks for designing and assessing the resilience of built assets to physical climate risks is required. These frameworks must permit consideration of lower-probability, higher-impact risks that result from all the Intergovernmental Panel on Climate Change (IPCC) emission scenarios.

Standards for building envelope performance, systems, equipment, and construction materials – including minimum energy performance standards – should complement building energy codes to progressively shift the market towards best-available technologies and low-carbon materials[6]. The most efficient technologies and low-carbon building materials tend to be more expensive than their conventional alternatives. Standards therefore need to be part of a comprehensive policy package including wider regulation and supporting measures such as subsidies, property tax incentives, mandatory energy planning etc., to drive market change.

Strengthening regulation is particularly relevant for heating, cooling and cooking technologies. Decarbonisation of heating and building renovations are vital to reduce direct emissions in buildings, 80% of which are associated with space and water heating. The majority of remaining direct emissions are associated with cooking, an end-use for which more than 2.3 billion people world wide still rely on rudimentary cook stoves, leading to 3.7 million premature deaths per year. Improving efficiency in space cooling equipment is also crucial to facilitate electricity demand reduction, especially during peak periods.

Adopting circular design presents a key opportunity to reduce material demand. All stakeholders within the value chain have an important role to play in creating early demand for reused materials and components. Government action is vital to the delivery of exemplar demonstration projects that can stimulate the supply market and set the context for training within the construction sector. This can be further supported by the inclusion of circular design policies in government procurement and construction guidance, as well as mandating energy renovations alongside structural ones. Other critical actions required to

[6] Recommendations associated with electric appliance standards (relating to electrical appliances across both buildings and industry) can be further explored in the Power chapter of this report; recommendations associated with construction materials standards can be further explored in the Steel and Cement chapters of this report.

promote the adoption of circularity include developing standards for the recertification of materials and components, establishing the infrastructure for the identification and storage of reused materials and promoting the deployment of product and buildings digital "passports".

Governments and private real estate developers should amplify demand through commitment campaigns for the procurement of near-zero emission and resilient buildings, enabling technologies and low-carbon construction materials. This can include the use of flagship public projects, where government-managed buildings can provide early demand signals to drive the sectors' development of critical skills, knowledge, construction practices and materials required to deliver near-zero emission and resilient buildings by 2030.

Unlocking private finance through clear and consistent policy and regulatory frameworks that support the development of near-zero emission and resilient buildings will be vital. This should include addressing uncertainty in the risks associated with investments in terms of cost to value and ensuring that physical properties are translated into metrics to inform financial decisions (e.g. certificates, labels, whole-life carbon assessments), including transitional risks of climate change to be accounted for in the valuation of built assets. A step change in the scale and effectiveness of financial and technical assistance will be required, particularly for emerging and developing countries.

Governments should jointly identify short- medium- and long-term research and innovation priorities and work closely with the industry to develop early-stage pilot and demonstration projects that can showcase front-running construction techniques, infrastructures, passive energy buildings design, circularity, clean technologies, processes, business models and approaches to deliver near-zero emission and resilient buildings/districts and renovations. RD&D efforts will continue to be needed over time, both to continuously improve building technologies to enable efficient operation in hard-to-reach market segments, and to ease their integration among practitioners, as well as to better understand the physical risk of climate change to cities and buildings and how to address these risks.

Governments, with support from the private sector, should support the delivery of training, retraining and reorientation to the workforce to enable the delivery of near-zero emission and resilient renovations and new builds. Countries that are leading the transition should also be among the first to share their learning with others, ultimately accelerating the transition for all. This includes the move from conventional construction practices and technologies to those that are near-zero emission and resilient, as well as raising the awareness of all stakeholders about new technologies, construction practices and resiliency strategies. Such efforts should contribute to identifying and developing job opportunities in the sector and support local labour unions in reskilling the workforce.

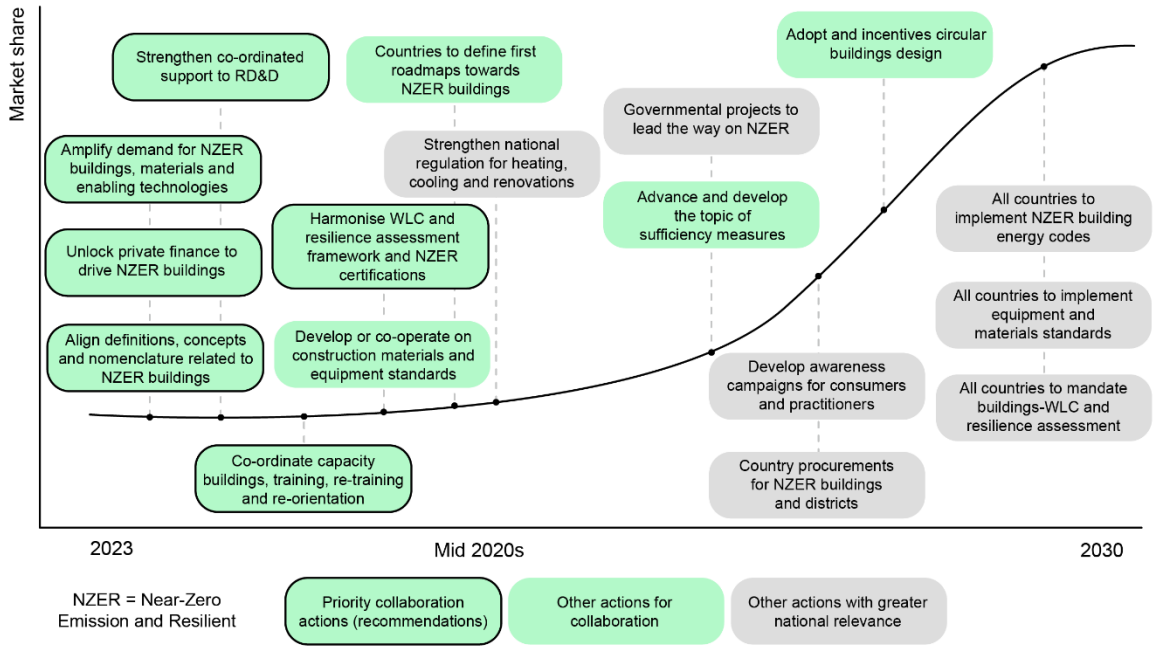
Sufficiency measure must complement the role played by efficiency, behaviour and renewables in the mitigation of emissions, as global growth in floor area is outpacing the existing efforts to decarbonise the sector.[7] There is a need to further develop and

[7] UNEP (2022), 2022 Global Status Report for Buildings and Construction; IEA (2023), Tracking Clean Energy Progress 2023.

encourage focus on sufficiency policies and interventions[8] in the sector. The IPCC Sixth Assessment Report notes that "At a global level, up to 17% of the mitigation potential in the buildings sector could be captured by 2050 through sufficiency interventions". The impact of sufficiency measures needs to be more widely understood, with implementation efforts led by developed countries which have a larger floor area per capita to repurpose, and less pressure from population growth and urbanisation.

Countries should also work to raise public awareness of near-zero emission and resilient buildings, as well as their enabling technologies and associated benefits, through dedicated communication campaigns. This will not only motivate people to reduce energy use and emissions, but also to achieve sustained change in technology choice. High-level ministerial engagements on the sector will provide a key platform to establish accountability on progress and maintain political focus.

Figure 6.1. Critical path to 2030 for the buildings sector



CURRENT STATE OF INTERNATIONAL COLLABORATION

International collaboration to support the transition to efficient, low-emission, resilient buildings has been driven by many global, regional and national initiatives, often running for many years. The buildings sector itself is highly fragmented, representing a large number of actors throughout long supply-chains (including manufacturers, public/private

[8] Sufficiency policies are defined by the IPCC as a "set of measures and daily practices that avoid demand for energy, materials, land and water while delivering human well-being for all within planetary boundaries," and sufficiency interventions are, for example, "density, compacity, bioclimatic design, multifunctionality of space, repurposing of existing unused buildings and moving from ownership to usership of appliances".

developers, labourers, architects, engineers, asset owners and tenants), operating within differing financing and regulatory environments across multiple projects.

As a result, co-ordination and alignment across these actors is a challenge, even more so internationally. Several initiatives aim to tackle this co-ordination challenge for the buildings sector by playing central organising roles for the whole sector or parts of it.

In an effort to improve the co-ordination of actions of countries and other actors in the sector, at COP 27, 16 countries – led by France and Morocco – and 13 initiatives/foundations together launched a call for the Buildings Breakthrough, with the vision: "***near-zero emission and resilient buildings are the new normal by 2030***". By September 2023, the number of countries and initiatives supporting the Breakthrough had increased to 25 and 15, respectively, with a full launch expected later in 2023.

The Buildings Breakthrough is co-ordinated under the umbrella of the Global Alliance for Buildings and Construction (GlobalABC) that was established at COP 21 in 2015. The Alliance is an umbrella organisation gathering all the stakeholders of the buildings sector value chain, and is the initiative with the highest governmental membership. It currently has 39 country members, who represent about 35% of global floor area, and about 240 members from initiatives and institutions from the public and private sector, including industry, civil society and academia. The activities of the GlobalABC are managed through multiple hubs, including resilience, materials, clean heat, data, finance and market transformation. The GlobalABC provides opportunities for exchange between member countries and organisations through an Annual Assembly and targeted events, such as at the COP's Buildings Pavilion and Regional Climate Weeks. It has been very active in delivering buildings sector roadmaps to 2050 for over 30 countries, in addition to providing the annual Global Status Report for Buildings and Construction publication.

The principal collaborative initiative in the private sector is the World Green Building Council (WorldGBC), working on the transformation to sustainable and decarbonised built environments. Together with 75+ Green Building Councils (GBCs), the first of which was founded in 1993, and their 46 000 members, WorldGBC aims to drive system change across key impact areas of climate action, resources and circularity and health, equity and resilience. This change is delivered through global programmes and regional networks. Work programmes and activities include the Advancing Net Zero programme, the Circularity Accelerator, the Better Places for People programme and their 'Global Policy Principles for a Sustainable Built Environment'.

Established in 1995, the World Business Council for Sustainable Development (WBCSD) also provides a forum for the private sector. It has more than 220 members, many of which are associated with the built environment value chain. The WBCSD hosts several programmes to support the transformation of the built environment, including on circularity, decarbonisation, digitalisation and finance, and leads a Market Transformation Agenda to provide a shared vision and actions for all stakeholders in the sector.

At the municipal level, C40 is a global network of local governments taking action to confront the climate crisis, aiming to halve the emissions of its member cities within a decade. C40 hosts a Net Zero Carbon Buildings Accelerator and Clean Construction

Accelerator. The International Council for Local Environmental Initiatives is also very active at the local level, with pathways towards low-emission, nature-based, equitable, resilient and circular development designed to create systemic change.

Other initiatives have a targeted focus on specific buildings and construction subsectors, areas of work (energy efficiency, resiliency and adaptation, finance, standards and certifications, etc) or geography.

The EnergyEfficiencyHub (EEHub) Energy Efficiency in Buildings Task Force, hosted by the IEA, is a government platform to exchange relevant policy information. It is led by Germany and the European Commission, and currently has seven members, with focus areas covering the life cycle perspective of emissions in buildings and deep retrofit models.

Co-ordination across initiatives focused on specific energy end-uses in buildings is also quite active, especially for cooling. Established in 2019, the Cool Coalition counts over 100 public and private partners to exchange knowledge, raise awareness and take action to accelerate the global transition to efficient and climate-friendly cooling solutions, including supporting the development of national action plans. The Clean Cool Collaborative (previously K-CEP) is a philanthropic initiative working towards efficient, climate-friendly cooling for all. On heating, the Clean Heat Forum was launched at COP 26, under the umbrella of the GlobalABC, with the aim of convening governments, industry leaders, experts and civil society to share best practice in policy-making between governments and the private sector and to accelerate the shift away from fossil fuels in the heating sector.

In terms of carbon measurement**,** standards, certification and regulation, there are many collaborative efforts involving technical experts along the supply chain in multiple sectors, supported by a number of organisations. United for Efficiency (U4E) provide Model Regulation Guidelines for governments to deploy energy efficiency regulations for lighting, appliances and equipment. Similarly, CLASP is involved with the development of energy performance standards for appliances. The Global Buildings Performance Network involves a network of individual experts, networks and alliances, and research, implementation and advocacy partners to support governments to develop and implement policy reform plans and roadmaps to decarbonise buildings and promote healthy, affordable housing, particularly in India and Indonesia.

National GBCs develop and administer voluntary green building certifications. The International Finance Corporation (IFC) EDGE certification programme, focused on developing countries, is also well-known. The International Organization for Standardization (ISO), an NGO, involves standardisation organisations from more than 160 countries, with the goal of sharing knowledge and developing relevant international standards across different products, processes, services and materials.

With the aim of driving large-scale change around advancing resilient solutions, Resilience Rising is a global consortium of NGOs and initiatives. One such initiative is the International Coalition on Sustainable Infrastructure, which aims to mobilise the engineering community to make resilience and sustainability the cornerstones of decision-making on infrastructure. Other initiatives include the Coalition for Disaster Resilient Infrastructure, Arsht-Rock, Roof Over Our Heads, and Build Change. In part due to a lack of standardised metrics, there is

limited experience and available data for understanding and tracking how resilience is being embedded in buildings design: the Notre Dame Global Adaptation Initiative developed country indexes to assess where the greatest needs and opportunities for improving resilience to climate change exist. The Cities Resilience Index provides a framework methodology for assessing resilience in cities, and the Building Resilience Index (IFC) a tool for assessing the resilience of buildings. REDi provides a set of prescriptive guidelines for implementation of resilience-based design into buildings.

With regards to delivering finance to support buildings decarbonisation, the IFC has efforts focused in this area, managing programmes such as the Market Accelerator for Green Construction. In the private sector, the Institutional Investors Group on Climate Change provides a forum for collaboration between major institutional investors on a net zero and climate resilient future, including real estate and across multiple regions. The group currently has over 400 members, who manage around USD 65 trillion of assets, although this cuts across many sectors beyond real estate. The Programme for Energy Efficiency in Buildings (PEEB) stimulates sustainable building design and construction through financing large-scale projects, policies and capacity building. In Europe, the Energy Efficiency Financial Institutions Group celebrated ten years of activities on buildings investment and finance (database, toolkits and white papers) in 2023.

Support for developing countries is being spearheaded by SEforALL, providing technical assistance and helping countries secure finance through several initiatives in clean cooking, cooling and energy efficiency.

There are several well-established forums to support public and private sector collaboration on RD&D. This includes the IEA's Technology Collaboration Programme (TCP), which includes the Energy in Buildings and Communities TCP, the District Heating and Cooling TCP, the Energy Efficient End-Use Equipment TCP, the Energy Storage TCP, the Heat Pumping Technologies TCP, Solar Heating and Cooling TCP, Photovoltaic Power Systems TCP, and the User-Centred Energy Systems TCP. In addition, Mission Innovation launched the Innovation community on affordable heating and cooling of buildings (previously Affordable Heating and Cooling of Buildings Innovation Challenge) in 2016, with 11 countries and the European Union currently participating. The International Council for Research and Innovation in Building and Construction (CIB) and the Climate Technology Centre and Network are also active in the area.

Overall, international collaboration around the buildings and construction sectors has been steadily increasing over recent years, covering a growing number of issues across decarbonisation and resilience. Despite this, high-level *intergovernmental* collaboration is somewhat limited compared with other sectors. In particular, there is a relatively low level of participation from the largest emerging economies, with one indicator of this being the absence of 65% of global floor area from participation in the GlobalABC. The initiative landscape, whilst very full, is relatively fragmented, suggested there are significant benefits from increased coordination.

This is partly due to the distributed nature of the buildings and construction sector and associated decarbonisation challenge, in which solutions are more localised than the global

solutions relevant for other sectors. In addition, as with other sectors, the buildings sector is not overseen or regulated by a single ministry or administrative body, but rather cuts across many different ministries (housing, energy, environment), with implementation and enforcement at a sub-national level in many countries.

There is therefore a significant opportunity to improve co-ordination and further strengthen international collaboration, accelerating the buildings sector towards a net zero and resilient future. Benefits from international co-ordination include learning from experiences in each country and from developers across different steps of the value chain, avoiding duplication of efforts, channelling resources where more are needed, and creating stronger incentives for investment in new solutions. To achieve this aim, countries should strengthen intergovernmental forums for convening and co-ordinating national government efforts in the buildings and construction sector.

PRIORITY AREAS FOR INTERNATIONAL COLLABORATION

WORK TOWARDS HARMONISING KEY DEFINITIONS, ASSESSMENT FRAMEWORKS AND CERTIFICATION OF NEAR-ZERO EMISSION AND RESILIENT BUILDINGS

OVERVIEW

Building codes, standards, certification and roadmaps are all important tools to help align expectations on the pace and trajectory of the transition in the buildings sector. Certificates also provide a way for buyers to differentiate between buildings, technologies and materials that are high-emission and low-emission, as well as allowing manufacturers and businesses a way to charge a premium in return for their investments.

Buildings energy codes have been central to improving the energy performance of new buildings. Transitioning towards near-zero emission and resilient buildings will require whole-life carbon and resiliency assessments, in addition to energy performance, to become the norm for buildings construction and major renovation projects.

Defining common measures of performance and risk assessment for whole-life carbon and resilience will help guide international investment, normalise corporate climate risk disclosure and improve international knowledge sharing on near-zero emission and resilient building design. Standards can be applied to the materials and technologies that are used in buildings, including steel and cement, as well as heating and cooling appliances.[9]

Certification schemes that define, assess and certify the performance of buildings are critical for strengthening confidence in near-zero emission and resilient projects among all

[9] Standards in relation to steel and cement are covered in more detail in the chapters on those sectors. The Power Chapter addresses the role of standards for electrical appliances, including those in buildings.

stakeholders. Robust certification of compliance with building codes and international standards will be required in order to identify, design and fund near-zero emission and resilient building projects.

National and/or sub-national roadmaps are useful instruments to align buildings stakeholders around a common pace and direction of policy change. Where possible, regional alignment on key policy milestones strengthens credibility and confidence in the pace of the transition across the regional value chain.

WHAT PROGRESS HAS BEEN MADE?

Knowledge sharing on building energy codes and their enforcements among early-mover countries has been supported by the IEA's EBC Programme which has had a Working Group on Building Energy Codes since 2019 (expected to end in 2024). In addition to ASHRAE and the International Code Council, this group currently has 12 country members, including the United States and China, representing nearly 50% of global buildings floor area.

The adoption and implementation of whole-life carbon methodologies is currently mostly voluntary, often leading to differences in declared performances. International efforts to harmonise such assessments are still rare.

Assessments of buildings' resilience to climate change are still uncommon. The GlobalABC adaptation working group is working to develop understanding of indicators for risk evaluation and possible actions on adaptation.

Knowledge sharing on building energy codes and their enforcements among early-mover countries are better understood thanks to the IEA's EBC Programme which has had a Working Group on Building Energy Codes since 2019 (expected to end in 2024). In addition to ASHRAE and the International Code Council, this group currently has 12 country members, including the United States and China, representing nearly 50% of global buildings floor area.

International collaboration efforts have also been active on voluntary standards and performance certificates. Voluntary codes and standards are a means to build capacity within the regional value chain and performance certificates are useful instruments for guaranteeing a verified level of quality.

Examples of voluntary standards that integrated new requirements include the ANSI/ASHRAE Standard 228-2023 Standard Method of Evaluating Zero Net Energy and Zero Net Carbon Building Performance, launched in 2023. International building certification schemes are also mostly private sector led. Among the most well-known international certifications, LEED (based in the United States) and BREEAM (based in the United Kingdom) are highly stringent voluntary green buildings certification schemes, which are often adopted by leading projects in developed countries. Depending on the project, these certifications often include requirements beyond carbon emissions, including health and social impact, and biodiversity. Passivhouse, initially developed for cold climates, is another widely used certification, with a clear set of indicators for performance of the

building envelope and energy needs for heating and cooling, and it has been expanded to cover warm climates as well. Emerging and developing countries often struggle to meet stringent requirements for certification schemes given a lack of supporting infrastructure, both in terms of skills and available materials, and of the administrative systems to collect and report the necessary data. To bridge this gap and provide a simpler quantitative approach, the IFC established the EDGE green buildings certification scheme, targeted at developing countries. While offering lower levels of ambition (in recognition of the challenge for developing countries) EDGE now offers a Zero Carbon certification (Level 3), which requires zero operational emissions, and partially considers embodied carbon.

For the operational phase of buildings, international certificates schemes that benefit from measured in-service energy consumption are also still very limited but would help bridge the gap between certified and real energy performances. One national example of such a scheme integrating monitored energy use data is the National Australian Built Environment Rating System.

WHAT MORE NEEDS TO BE DONE?

There is a clear role for improved international collaboration, especially for aligning definitions and nomenclature for near-zero emission and resilient buildings and harmonising compatible whole-life carbon and resilience assessments.

Wherever possible countries should work through existing forums to harmonise – or at least make interoperable – the definitions for near-zero emission and resilient buildings. Developing a common set of concepts and nomenclature, established in international standards such as EN-ISO 52000, would facilitate communication across international stakeholders and avoid ambiguity over terms. While perfect alignment of standards requirements is unlikely to be practical, alignment on key definitions and nomenclature is critically important to provide clarity for all stakeholders and facilitate investment decisions internationally.

Countries should work towards harmonising and aligning whole-life carbon assessments for near-zero emission and resilient buildings to reduce the administrative burden for actors that operate internationally and simplify incentives for investors. Furthermore, there is a need for countries to work towards developing and harmonising resiliency assessments. Resilience metrics for buildings should also be co-ordinated with broader city/settlement resilience assessments.

Sufficient flexibility should be built into these approaches to identify and accommodate localised regional climate risks and construction practices. There will also be a need for guidance on using WLC and resiliency assessment in cases where data is unavailable.

The harmonisation/ development of WLC and resiliency assessment should be supported by establishing shared formats, mechanisms and international platforms for data and knowledge sharing, to help ensure that data are accessible and comparable across projects in different countries, simplifying investment decisions.

International sharing of best practice in assessing and certifying compliance with near-zero emission and resilience standards can also be helpful and can play an important role in upgrading certification processes, as well as methods and tools for implementing and reinforcing national certification schemes. This can be supported by the development of international technical roundtables and training programmes, which make use of the latest tools and data, and can build local capacity.

Where possible, regional alignment on key policy milestones within national and sub-national roadmaps strengthens credibility and confidence in the pace of the transition across the regional value chain. This confidence helps de-risk public and private investment in the sector.

> RECOMMENDATION B1:
>
> Governments should work together to harmonise and upgrade the definitions and nomenclature for near-zero emission and resilient buildings and their performance. Countries should work towards harmonising whole-life carbon assessments, developing resilience assessments, and aligning certification scheme with near-zero emission and resilient requirements. Harmonisation should permit the flexibility to accommodate different regional contexts and should be supported by establishing shared international mechanisms, platforms and formats for data sharing of best-in-class near-zero emission and resilient projects.

AMPLIFY DEMAND FOR NET ZERO EMISSIONS AND RESILIENT BUILDINGS, CONSTRUCTION MATERIALS AND CLEAN ENERGY TECHNOLOGIES

OVERVIEW

Creating and signalling demand de-risks the transition and incentivises capacity building for all actors in the value chain. International co-ordination has a key role to play in strengthening and amplifying the pace and direction of transition through public demand signals and joint policy objectives.

While economically profitable over their lifecycle in the majority of projects, near-zero emission and resilient buildings and enabling technologies often command a premium upfront capital cost compared to their conventional, higher emission equivalents. To help create an early market for these products, procurement commitments that promise to cover the premium can support the scale-up in manufacturing and installation that can drive down costs, ultimately reducing the need for ongoing policy support. Co-ordinating such

commitments across multiple countries and companies can create larger shared markets for materials and appliances, as well as for whole building approaches in line with net zero ambition by mid-century, providing the sector with increased confidence to invest.

In addition, defining joint policy objectives (e.g. doubling renovation rates by a certain year) can also provide the industry with the predictability needed to encourage private sector investment.

WHAT PROGRESS HAS BEEN MADE?

Procurement commitments have been made for construction materials and building appliances in particular, which are often mass-produced and highly traded, and for which co-ordinated governmental engagement in existing procurement campaigns already exists. Ongoing campaigns include the Green Public Procurement Campaign of the Clean Energy Ministerial Industrial Deep Decarbonisation Initiative (IDDI), Steel Zero, Concrete Zero, and the First Movers Coalition (Aluminium, Steel, Cement and Concrete).

Beyond materials and appliances, co-ordinated procurement commitments on net zero and resilient buildings may be aggregated through international buyers' alliances. Examples of private sector initiatives in this space include WorldGBC's Net Zero Carbon Buildings Commitment, UK Better Building Partnership's Climate Commitment, Climate Group EP100 and C40's Clean Construction Accelerator.

There are currently no government-led initiatives in this space, which could provide an opportunity to further strengthen the demand signal and facilitate learning between countries on green procurement policy related to buildings. Joint commitments to policy objectives with a defined timelines are also powerful instruments to drive demand. C40's clean construction and net zero carbon buildings accelerator programmes are strong examples of existing joint policy commitments at sub-national level. For appliances, the principal collaborative forum is CEM SEAD, which includes a Product Efficiency Call to Action, covering indoor lighting, residential air conditioners, residential refrigerators and industrial electric motor systems.

WHAT MORE NEEDS TO HAPPEN?

National and sub-national governments should join existing international initiatives aggregating procurement commitments for near-zero emission construction materials. This will help to strengthen signals for investment, and bring down the cost of near-zero emission production of materials such as steel and cement (see the chapters on those sectors for more details).

A priority going forward is to create joint procurement commitments for near-zero emission and resilient buildings projects. Such commitments should provide a common platform to aggregate both public and private-sector investment as well as mobilising tenant demand. This would go beyond creating demand for zero emission versions of currently-used materials, and begin to drive demand and supply-side capacity for whole-life carbon and

resilience assessments, exploring new building designs, and new approaches to efficiency in buildings' construction and operation. Government buildings and public projects are a natural segment of the market for government procurement to address first.

Knowledge sharing between governments and co-ordinated delivery of exemplary demonstration projects can significantly support the industry to build capacity and gain experience in order to meet future demand for near-zero emission and resilient buildings. In addition, aligning guidance and practices within public registries also plays an important role in successfully delivering such projects.

Beyond procurement, joint commitments to align the regulatory milestones should also go beyond current existing ones on air conditioners and electrical appliances, and extend to key clean and efficient heating and cooling technologies, in particular.

> RECOMMENDATION B2:
>
> Governments should jointly create and strengthen procurement commitments for near-zero emission and resilient buildings, as well as joining existing material procurement alliances. Countries should work to establish new joint commitments on deploying clean and efficient heating and cooling technologies.

CO-ORDINATE EFFORTS TO IMPROVE TECHNICAL AND FINANCIAL ASSISTANCE TO UNLOCK PRIVATE INVESTMENTS

OVERVIEW

A step change in investment will be required to support the decarbonisation and adaptation of the buildings sector and supporting infrastructure. While it is challenging to track total investment given how fragmented the sector is, investment in energy efficiency and electrification[10] in buildings is estimated to have increased to about USD 285 billion in 2022, up from less than USD 200 billion in 2020. While still significantly above levels from 2014 to 2019, investment is not expected to grow further in 2023. National public spending programmes are largely limited to European countries, which led the increase in response to the energy crisis and lower household budgets, and to the United States, through its continued funding for energy efficiency. By 2030, annual levels of investment need to more than double to support the sector's transition to net zero. The investment gap is particularly large in emerging markets and developing economies, which contribute the majority of the forecast growth in floor area, where public investment remains low, and supporting

[10] Including investments in new efficient equipment, deep renovation, and zero-carbon-ready buildings.

regulation and policies – particularly stringent building energy codes – are not yet in place. In addition, the greater focus on affordability and basic provision of shelter in developing countries may mean that – without additional support – sustainability criteria are deprioritised.

WHAT PROGRESS HAS BEEN MADE?

Several well-established collaborative forums exist to support increased investment in buildings to overcome these challenges. Multilateral development banks (MDBs) and IFIs have many years of experience in supporting low-carbon projects in emerging markets and developing economies, with the IFC, International Bank for Reconstruction and Development and European Bank for Reconstruction and Development channelling a large share of the budget delivered to projects. To facilitate collaboration on this topic, the GlobalABC convenes a Finance Hub, co-chaired by IFC and PEEB, with a recent focus on the tools and methods that can support IFIs as they develop a portfolio of projects. Since COP 26, PEEB has also started working with the International Development Finance Club to support development banks' collaboration around green buildings.

Among the G20, the Energy Efficiency Task Force Group (EEFTG) was established with 15 of the G20 countries as its members. The EEFTG conducted useful work which countries could build upon, including investment principles, private sector convening and MDB co-ordination.

There are also many private sector collaborative efforts, including the WorldGBC Sustainable Finance Taskforce, the Net Zero Asset Managers Initiative, the Net-Zero Asset Owners Alliance, the Paris Aligned Asset Owners initiative, GFANZ and the Global Innovation Lab for Climate Finance. At a sub-national level, the Cities Climate Finance Leadership Alliance has also been working with municipal governments to mobilise investment.

WHAT MORE NEEDS TO BE DONE?

Overall, there is a need for a significant increase in the technical and financial assistance made available for developing countries to support the transition. This principally includes private finance, mobilised by the appropriate policies. However, greater public support will also be required to kickstart a pipeline of projects that would otherwise be seen as too risky if left to private finance alone. Developed countries should review the available funding on offer to support near-zero emission and resilient buildings in developing countries, committing to increase the level of funding available.

To better mobilise private investment, as mentioned above, building ratings or certificates are a critical mechanism for providing assurance on genuinely sustainable projects for investment. A lack of clear co-ordination among certification schemes, or minimum rating standards, presents a barrier to international investment, with investors and consumers unclear on how schemes differ and if they will deliver outcomes in line with national or

company-level targets. Better aligning these schemes will help accelerate the mobilisation of private finance, reducing complexity in the verification of sustainable investments.

Beyond a lack of co-ordination on certification schemes, there is a co-ordination challenge in the delivery of financial and technical support for turnkey decarbonisation projects, especially in emerging and developing economies. Due to the large number of different IFIs, funds, and private investors who are looking to support low-carbon projects, it can be challenging for national and regional governments in emerging and developing countries to match their requests for support with the right funding and technical partners. In many cases, developing countries require support to develop project proposals before they are submitted for large-scale funding by one of the major IFIs. The main challenge is not necessarily attracting more finance but rather using the existing funds more effectively, by matching partners together and supporting recipient countries through the whole process, from project ideation to completion.

To help overcome this challenge and to make best use of public and private funds, a dedicated matchmaking platform should be established for stakeholders in the built environment sector, including private sector investors. Such a platform should provide single point of contact for developing countries who are looking to access support, with donor countries, MDBs, national development banks (NDBs), private financial institutions and investors, philanthropic organisations, buildings and real estate companies and technical assistance partners all involved. It should cover both financial support for major flagship projects, and policy matchmaking to help unlock a pipeline of projects. Policy matchmaking would involve countries that are further along in the transition sharing experience of developing and implementing certain buildings decarbonisation policies, to ensure individual projects can motivate larger changes in the sector. This model has worked well in other sectors, including power (see Energy Transition Council) and road transport (see Zero Emission Vehicle International Assistance Taskforce).

To further support private sector investment, such a platform could take on the role of grouping together projects, where appropriate, lowering the risks for investors. The platform should also facilitate improved learning around the use of innovative financial instruments and project design that have proved to be successful. This includes government-backed zero-coupon renovation loans, green mortgages and property assessed clean energy (PACE) loans.

It will also be important that investors increasingly embed physical climate risk assessments into investments, both within MDBs and the private sector. This in turn can be supported by aligning with requirements to disclose climate risk in investments, building on successful international agreements such as the G20 announcement to support the Taskforce on Climate-related Financial Disclosures framework.

RECOMMENDATION B3:

Countries should increase the scale of funding available for near-zero emission and resilient building projects, as well as improving the co-ordination of assistance going forward through the establishment of a establish a matchmaking platform dedicated to the delivery of near-zero emission and resilient building projects. This platform would act as a single point of contact for emerging and developing countries, with support from donor countries, MDBs, NDBs, private financial institutions and investors, philanthropic organisations, buildings and real estate companies and technical assistance partners.

CO-ORDINATE SUPPORT FOR RESEARCH, DEVELOPMENT AND DEMONSTRATION TO ACCELERATE THE DEPLOYMENT OF KEY TECHNOLOGIES AND CONCEPTS

OVERVIEW

Compared to other sectors, the buildings sector has already started deploying many mature technologies for clean energy and efficiency. However, there are several hard-to-reach market segments and concepts for which innovation will be critical. While experience on RD&D for buildings design and technologies has made progress over many years, there are some emerging research areas and market segments which are receiving less attention from international research collaboration networks. This might be linked to the lack of certain expertise in existing well-consolidated international research networks and/or to the lower membership of emerging and developing countries in existing research programmes.

WHAT PROGRESS HAS BEEN MADE?

International collaboration on RD&D has been quite active in the buildings sector, spanning from the IEA Technology Collaboration Programmes (TCPs), advancing research, development and commercialisation of building energy technologies, to the Mission Innovation Challenge Innovation Community on Affordable Heating and Cooling of Buildings (IC7), which aims to share a common understanding of global RD&D priorities for heating and cooling and to identify collaboration opportunities. The IEA TCPs' working group on buildings has made efforts to identify priorities for research collaboration and in mid-2022 published a report highlighting some of the priorities for strengthening innovation and collaboration related to their respective work areas. The same TCPs hosted the IEA Future Buildings Forum Think Thank Workshop in late 2022 to discuss research priorities for existing buildings.

Innovation has also been driven by the Clean Cool Collaborative (previously K-CEP), Cool Coalition and Rocky Mountain Institute. The Global Cooling Prize and Million Cool Roof Challenges stand out as technology prizes driving innovation in the sector. In late July 2023, a Global Cooling Efficiency Accelerator was launched to bring innovative products to the market.

Significant progress has been achieved by internationally led research, especially with regards to advances in individual technologies, such as heat pumps, superinsulation materials and storage.

WHAT MORE NEEDS TO BE DONE?

Research areas with critical importance for policy priorities in the sector include assessing and designing building resilience, assessing embodied emissions, advancing understanding of the role of sufficiency, near-zero emission and resilient construction practices for different building types, circular design, passive building design and construction, energy management systems, and clean and efficient space cooling and heating technologies.

Research must also reach beyond technologies alone, such as to better understand stakeholders' engagement over the value chain and user acceptance of innovative technologies. Innovation will also be required to train practitioners on how to operate and integrate new technologies in their daily practices, to enable technologies to operate together, and to develop business models and align incentives that can increase the affordability of new technologies.

To advance the role of 'sufficiency' within the sector, countries should co-ordinate on harmonising common definitions, establishing international tracking metrics (e.g. the growth of floor area per capital), identifying effective sufficiency policies, elevating platforms for sharing and advancing the topic within the sector.

To further improve collaboration in this area, countries should build on existing networks to align near-, medium- and long-term RD&D priorities to evolving policy goals. This should include developing shared, credible technology innovation roadmaps**,** and a system to review and track progress against such a roadmap, providing a vision to align actors with a clear direction of change.

To increase participation of emerging markets and developing economies in existing multilateral networks, countries should define processes to accelerate the creation of flexible joint programmes. This is also key to enabling global deployment of emerging technology solutions. The creation of flexible joint programmes could, for example, be eased through the development of a list of experts who are available to collaborate on a certain topic.

Countries should further facilitate the sharing of skills and knowledge by expanding existing platforms for international knowledge sharing to integrate vocational training on how to install, operate and maintain new technologies and practices. Such platforms should also

improve access to high-quality research (e.g. by co-ordinating on criteria for high-quality research and publication standards); reviews of state-of-the-art materials, technologies and construction techniques; and work to communicate research beyond a technical audience.

Countries should co-ordinate efforts on the demonstration and early adoption of new technologies for public projects and put in place the necessary infrastructure to enable conditions for testing, operating and commercialising new technologies, which can be a vital tool to showcase what is possible and share that learning with a wider network.

> RECOMMENDATION B4:
>
> Countries and companies should work together to identify knowledge gaps that can be overcome via joint working, and align RD&D priorities to shared policy goals. Countries should also facilitate the expansion of existing networks to bring in new expertise and country members, and work through those networks to improve communication of high-quality research and best practice, and deliver training to deploy innovative technologies, construction practices, tools and business models at scale, using government projects to lead the way.

IMPROVE THE TRAINING AND CAPACITY BUILDING OFFER FOR STAKEHOLDERS ALONG THE VALUE CHAIN, IN BOTH THE PUBLIC AND PRIVATE SECTOR – WITH A FOCUS ON BUILDING ENERGY CODES

OVERVIEW

The success of government policies, financial incentives, regulations and schemes in reducing carbon and improving the resilience of the buildings sector will depend on the availability of a skilled workforce to implement these changes. The shortage of "green-collar" professionals with cutting-edge skills in energy efficiency, low-carbon engineering, and skilled construction labour has been identified in a number of countries as a major bottleneck in the transition to sustainable construction practices.

This can be addressed by embedding environmental sustainability, resource efficiency and climate resilience within all mainstream learning, including national curricula, apprenticeships, degrees and professional qualifications.

Addressing the lack of understanding of energy efficiency, resiliency and sustainability within the built environment workforce will be very valuable for a sector which employs more than 200 million people and more than 90% of the operators are SMEs. All players in

the industry must understand the impact their contribution makes to the performance of buildings and the interdependence of all those involved throughout the building lifecycle stages, from design to end of life.

National and sub-national building energy codes have been central to improving the energy performance of new buildings. Emerging and developing economies largely do not have stringent building energy codes in place. Capacity building needs to focus on supporting these countries with implementing and increasing the stringency of building energy codes. Such efforts need to be guided by tracking the present stringency of energy codes internationally.

WHAT PROGRESS HAS BEEN MADE?

There are several existing international collaborative initiatives that support capacity building and training for the buildings sector. For instance, the Global Universities Partnership on Environment and Sustainability (GUPES), the Education for Sustainable Development (ESD) and International Sustainable Campus Network (ISCN) aim to support the incorporation of sustainability – including sustainable construction – into education at all levels. The International Labour Organization's Skills for Green Jobs Initiative aims to promote the development of skills and competencies that are relevant to green jobs across various sectors, including construction.

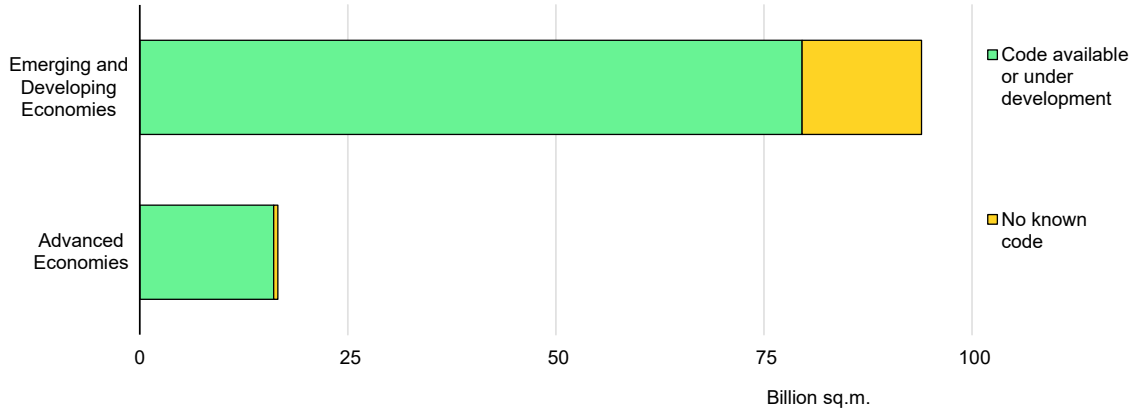
There are also regional initiatives that address the skills gaps and shortages in the construction sector related to energy efficiency and sustainable building practices, such as the European Union's BUILD UP Skills initiative.

A number of networks and international partnerships such as WorldGBC and GlobalABC provide resources, training programmes and guidance for governments and professionals on green building practices, promoting sustainable design and construction globally. The IFC's EDGE programme provides training and certification for professionals in green building design and construction. The Getting to Zero platform provides resources and opportunities for knowledge sharing and advanced learning. These initiatives and collaborations aim to enhance skills, knowledge and awareness among professionals involved in the construction industry. By sharing best practices, providing training programmes and fostering networks, these international collaborations contribute to the global adoption of sustainable building practices and the achievement of climate and sustainability goals.

The IEA Energy Efficiency Training Week, which since its launch in 2015 has involved more than 2 000 professionals, primarily from government institutions and from more than 120 countries, represents a successful example of sharing experiences and best practices for planning, implementing and evaluating energy efficiency policies in emerging economies.

Today, over 90 countries have implemented mandatory or voluntary codes for either the buildings sector or the non-residential segment. However, about 15% of expected floor area growth by 2050 in emerging and developing economies is not currently covered by building energy codes at all (see Figure 6.2) – more than the combined floor area of France, Italy and Germany today.

Figure 6.2. New floor area additions from 2023 to 2050 by coverage of building energy codes



Sources: IEA (2023), Tracking Clean Energy Progress 2023; UNEP (2022) 2022 Global Status Report for Buildings and Construction.

International collaboration efforts on building energy codes among early-mover countries are better understood thanks to the IEA's EBC Programme which has had a Working Group on Building Energy Codes since 2019. In this group, countries exchange knowledge on how to formulate and implement buildings energy codes, sharing lessons learned to accelerate the process for others. It will be important to synthesise learning from this group (which is expected to end in 2024) in order to increase knowledge on buildings codes among a larger group of countries, and to develop materials and technical support for emerging and developing countries in particular.

Developing, upgrading and implementing new buildings energy codes is often a very challenging, lengthy and complex process. Building energy codes that integrate carbon metrics are currently rare, and those that integrate resilience metrics even more so. Ambitious metrics have only been adopted by first-mover regions, countries or sub-national entities.

WHAT MORE NEEDS TO BE DONE?

International collaboration and knowledge transfer on training and capacity building for net zero and resilient buildings and construction can help accelerate the adoption of sustainable construction practices worldwide.

Efforts towards this aim should focus on strengthening the existing forums, platforms and networks that facilitate the knowledge sharing, including through digital learning platforms with content accessible in different languages. International collaboration can help to support curriculum development, encourage experiential learning and exchange programmes, and strengthen partnership and resource sharing. Technical assistance and capacity-building support for developing training programmes is particularly urgent in countries with limited resources. The development and co-ordination of international data sharing platforms will further support efforts to harmonise on key areas.

There is also a need to develop international guidelines and accreditation frameworks for education and training. Harmonisation efforts will enhance the transferability of skills and qualifications, facilitate international mobility of professionals, and promote global recognition of education for high-performing buildings.

Co-ordinated capacity building needs to focus on supporting developing countries – who will contribute most significantly to floor area growth – with implementing and increasing the stringency of buildings energy codes. This capacity building will need to be enhanced by tracking of energy code stringency and supported by finance for development and implementation of such codes.

RECOMMENDATION B5:

Countries and companies should jointly identify knowledge gaps and define training and capacity-building priorities, strengthening the role of existing networks to share knowledge and provide guidance, tools, and resources to build capacity across all regions. This includes a focus on supporting developing countries with implementing and increasing the stringency of building energy codes. Countries should also work together to assist in curriculum design, implementation of training programmes and accreditation frameworks to enhance the transferability of skills and qualifications, and ultimately promote net zero and resilient building practices.

RECOMMENDED REPORTS

Human Settlements - Climate Action Pathway 2021 (UN, 2021).

Market Transformation Levers for a Net Zero Built Environment (WBCSD, 2021).

Global Policy Principles for a Sustainable Built Environment (WorldGBC, 2023).

Adaptation of the Building Sector to Climate Change: 10 Principles for Effective Action (GlobalABC, 2021).

Technology and Innovation Pathways for Zero-carbon-ready Buildings by 2030, A strategic vision from the IEA Technology Collaboration Programmes (IEA, 2022).

2022 Future Buildings Forum Think Tank Workshop. Existing Buildings: Pathways to Net Zero Carbon by 2035 (EBC TCP, 2022).

2022 Global Status Report for Buildings and Construction (UNEP GlobalABC, 2022).

Net-zero buildings: Halving construction emissions today (Arup, WBCSD, 2023).

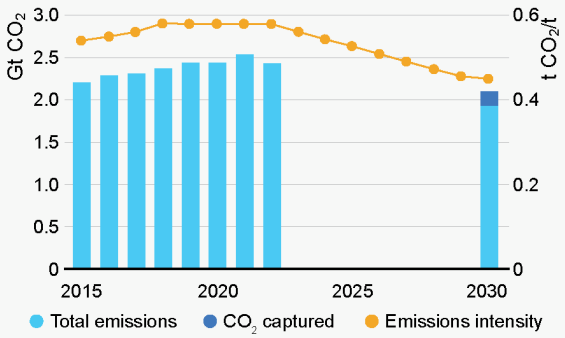
EBC Working Group Final Report: Scan of Code Requirements to Address Greenhouse Gas Emissions (EBC TCP, 2023).

Tracking Clean Energy Progress 2023 [Buildings, Building Envelopes, Heating, Space Cooling, Lighting, Appliances and Equipment] (IEA, 2023).

CEMENT

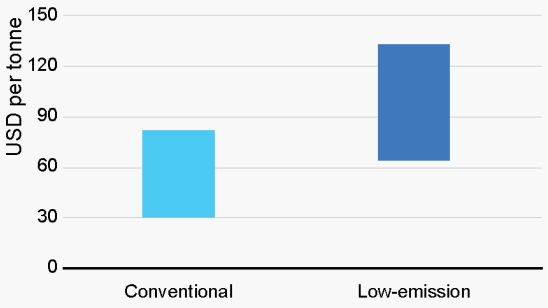
The cement sector is not on track to meet net zero by mid-century, with total emissions rising since 2015. A significant number of new high-emission cement plants are anticipated, with relatively few announcements for new near-zero emission cement projects.

Emissions[1]



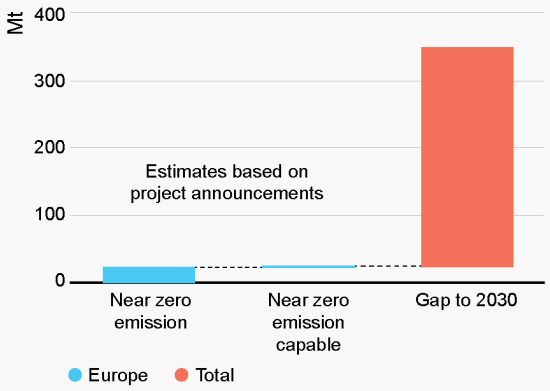
- Total CO_2 emissions from the cement sector have been rising since 2015.
- Emissions intensity of cement production has risen by nearly 10% since 2015, largely due to an increase in the clinker-to-cement ratio in China.
- By 2030, total emissions need to fall by around 20%, enabled in part by an increase in CCUS.

Costs[2]



- During the 2020s, costs of producing near-zero emission cement are likely to remain significantly higher than conventional cement.
- While a range of different low-emission technologies are under development, current estimates put low-emission cement at a 75% premium versus conventional cement production, on average.

Deployment[3]



- Current announcements for near-zero emission[4] cement production by 2030 are at 22 Mt, plus 2 Mt near-zero emission capable.
- The pipeline of projects has increased somewhat in recent years but remains a long way from the approximately 350 Mt required to get on track for net zero.
- By 2030, around 8% of global cement production capacity needs to be consistent with near-zero emissions.

[1] Notes: LH axis = total emissions (bar); RH axis = emissions intensity (line). Source: IEA (2023), Tracking Clean Energy Progress: Cement.
[2] Source: IEA (2023), Energy Technology Perspectives 2023.
[3] Source: IEA (2023), Energy Technology Perspectives 2023.
[4] "Near-zero emission" refers to projects that, once operational, will be near-zero emission from the start, as defined in the IEA report Achieving Net Zero Heavy Industry Sectors in G7 Members. "Near-zero emission capable" refers to projects that will achieve substantial emissions reductions from the start – but fall short of near-zero emissions initially – with plans to continue reducing emissions over time such that they could later achieve near-zero emission production without substantial additional capital investments in core process equipment.

HOW DO WE GET THERE?

Standards and definitions for low and near-zero emission cement and concrete production will be important to support multiple enabling policies and commitments. They need to be agreed among cement and concrete producers and consumers – including governments – to avoid the development of multiple competing standards, which can confuse consumers and slow the transition. These definitions should be supported by robust and interoperable emissions accounting methodologies, recognised in international standards. These should also be aligned with the approach being taken for other materials, such as steel, to ensure a fair comparison and should look to define thresholds for intermediate products, such as clinker, where relevant.

Net zero compatible standards and guidelines for cement use and construction design regulations will also be vital to facilitate the efficient use and, where appropriate, reuse of clinker, cement and concrete. Improved material efficiency will be crucial to help reduce overall demand for clinker, cement and concrete, reducing the challenge for decarbonisation. This will require working along the supply chain, including final consumers, architects, structural engineers, designers, builders' merchants, bankers and more, to agree common approaches for decarbonisation at different steps of the supply chain, and to exchange knowledge and best practice.

Early demand for low and near-zero emission cement will be facilitated by these definitions and standards, helping provide market certainty. Various measures can help support the creation of a lead market for low and near-zero emission cement, including purchase commitments from the private sector, and policies including public procurement guidelines, standards and mandates, and carbon contracts for difference (CCFDs). Aggregating these commitments across countries, initiatives and policies will help send a stronger demand signal, further mobilising early investment in projects.

Governments and companies should increase RD&D investments and knowledge exchange to accelerate multiple pilot and demonstration scale projects around the world. This should include a mix of technology solutions, including near-term efficiency improvements; carbon capture, utilisation and storage (CCUS); clinker from non-carbonate sources; supplementary/alternative cementitious materials; alternative binding materials; and fuel substitution (e.g. bioenergy, renewable waste, electricity or hydrogen). As exploratory RD&D projects de-risk key deep decarbonisation technologies, governments can support the first wave of commercial-scale plants from the mid-2020s through policy and regulation.

Governments should provide appropriate support for early commercial-scale deployment, supporting rapid scale-up of low-emission production both through new-builds and retrofits of existing plants. This includes the use of direct subsidies on capital and/or operational costs, mechanisms to de-risk finance, carbon pricing, mandatory standards and more, depending on a country's existing policy framework and intended outcomes. Where necessary, this should include creating a level playing field for low and near-zero emission cement and facilitating trade across borders. Complementary policies, such as retrofit-ready requirements that ensure adequate space and technical

considerations for future incorporation of near-zero emission technologies are in place when planning new unabated plants, can help to prevent emissions lock-in while deployment is still scaling up.

Governments and companies should establish and communicate early on long-term strategies and set milestones for deep decarbonisation, providing greater certainty on the direction of travel. These strategies should detail the important interactions with other sectors, such as power and buildings, that will have a significant impact on the pace of the transition in the cement sector. Alongside policies to boost the deployment of key low-emission material production technologies, such strategies should also set out policies to encourage material efficiency and circularity, in close consultation with supply chains. This in turn can provide certainty for public and private investors around the technologies and emission reduction approaches for the sector. Strategies and milestones should be revised regularly as technology and policy pathways evolve, while maintaining a focus on decarbonisation.

Governments and companies will need to work closely together to develop effective international technology development and deployment partnerships, potentially underpinned by technical and financial assistance, ensuring involvement from all major cement-producing regions. As can be observed with already-announced projects, it is likely that companies in Europe and North America will lead on early deployment of innovative, near-zero emission technologies over the mid-2020s. Beyond these first few projects, additional projects should be taken forward across the globe, supported by learning from these early examples and enabling operation later this decade.

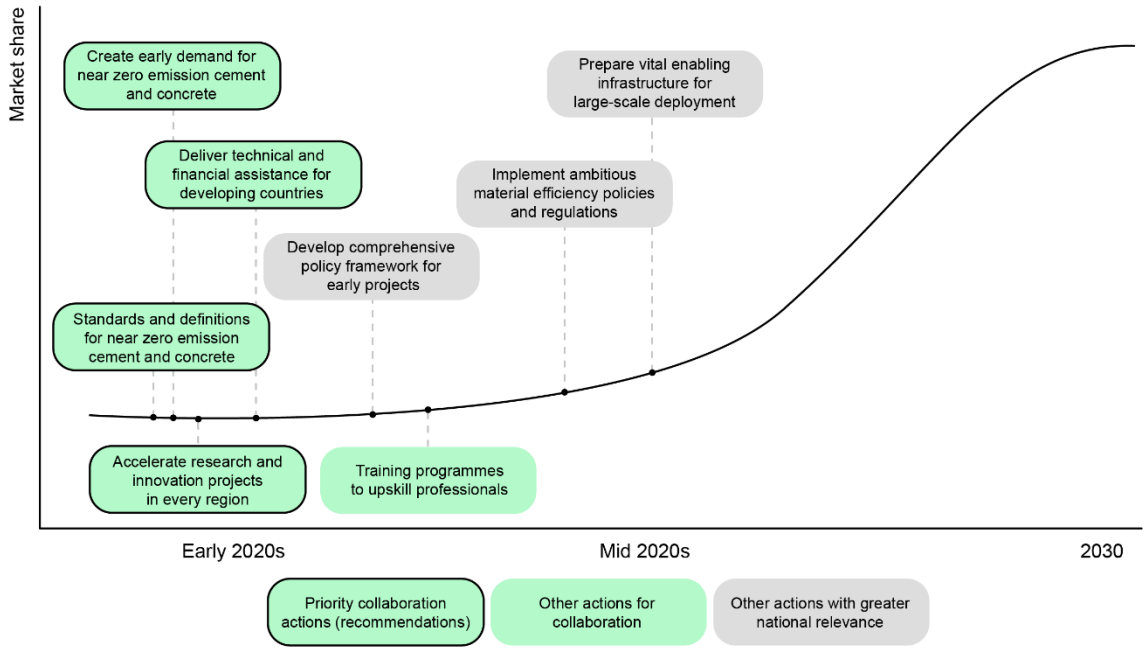
Governments and companies should work proactively to prepare vital enabling infrastructure for key industrial sites – including CO_2 transportation and storage, most importantly, as well as hydrogen and electricity infrastructure, where needed. Given the generally longer lead-times for infrastructure, this should include planning well in advance, and making use of early learning on rapid infrastructure deployment, including novel regulations, accelerated permitting, plant operation and CO_2 infrastructure integration. It is important that such approaches remain inclusive of local communities' concerns and priorities; information campaigns and proactive community engagement will be vital. Rapid feedback loops, supported by international initiatives, can help ensure that near-zero emission plants and their enabling infrastructure are built in a wider set of countries as quickly as possible.

A significant increase in the availability of skilled professionals will be required to support these projects, including engineers, architects, construction workers, carbon management and renewable energy experts, capable of supporting the deployment of new near-zero emission cement plants and deploying material efficiency strategies. This will require both retraining programmes for existing employees, as well as an increase in appropriate graduate and early-career training and qualifications.

For these actions to be realised, there is a need to focus and co-ordinate international efforts in the cement sector, as well as with other industry sectors. Only with effective

international collaboration will it be possible to ensure that the transition can occur at the pace and scale required, and that near-zero emission solutions are affordable and accessible to all.

Figure 7.1. Critical path to 2030 for the cement sector



CURRENT STATE OF INTERNATIONAL COLLABORATION

International collaboration to support cement sector decarbonisation is well developed in the private sector, but is only at a relatively early stage between governments, with activity starting to accelerate in the past few years. The cement sector exhibits a relatively high degree of market concentration, with the top four companies responsible for about 20% of global cement production (two headquartered in Europe and two headquartered in China). As a result, there is potential for accelerated sharing of knowledge across borders, as many companies operate in several regions.

The Global Cement and Concrete Association (GCCA), established in 2018, is an industry body that focuses on decarbonisation, with 43 member companies representing 80% of global cement production outside China (China represents about half of global cement production). Key activities include: the GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete, an initiative to translate global commitments into local action through national technology, policy and project roadmaps; a member Sustainability Charter and guidelines; a CO_2 emissions and energy, annual reporting and benchmarking

database (GNR 2.0[1]); an externally verified Environmental Product Declaration software tool for members and non-members; and Innovandi, which encompasses two global innovation platforms that address both pre-competitive and applied innovation activity through an industry and academia research consortium, and a startup accelerator scheme.

The World Cement Association (WCA) was established in 2016, with 36 full corporate members and 25 associate corporate members. It also undertakes several activities in support of decarbonisation, including the Plant Evaluation, Gap Analysis and Support Service (PEGASUS) Programme.

Creating lead markets through early demand commitments has been an area of collaboration that has seen rapidly growing interest in recent years. Among governments, the principal initiative in this space is the Clean Energy Ministerial's Industrial Deep Decarbonisation Initiative (IDDI), which was established in 2021 with the United Nations Industrial Development Organization (UNIDO) as the secretariat to support the creation of demand through green public procurement. IDDI currently includes 10 member countries, who account for about 16% of global cement demand. In the private sector, the leading global initiatives include ConcreteZero, which was established in 2022 to co-ordinate company commitments and unify private sector demand for using 100% net zero concrete by 2050 at the latest, as well as 30% low-emission concrete by 2025 and 50% by 2030. The First Movers Coalition (FMC), which was launched in 2021 (with cement and concrete added in 2022), also works with companies to co-ordinate their commitments, targeting 10% near-zero emission cement/concrete by 2030.

In terms of certification and standards, alongside GCCA's ongoing work, the Concrete Sustainability Council (CSC) was launched in 2016 by the World Business Council for Sustainable Development (WBCSD). The Council provides a responsible-sourcing certification system, grading building materials facilities on environmental and social responsibility, and governance.

Early technologies have also been a focus for collaboration efforts, with several established networks for sharing learning on CCUS, including the Global CCS Institute and the CEM CCUS Initiative, the latter of which has agreed a formal co-operation with GCCA to scale up CCUS deployment in the cement and concrete industry. Beyond CCUS initiatives, the Mission Innovation Net Zero Industries Mission (NZIM) was launched in 2022, co-led by Austria and Australia, with eight other government members. NZIM aims to accelerate novel industry technologies' time to commercialisation through improved national and multinational co-ordination of R&D efforts.

Beyond these global efforts, there are strong and long-established regional cement and concrete organisations in Europe (Cembureau, European Ready mixed Concrete Organization [ERMCO], Federation of the European Precast Concrete Industry [BIBM], Concrete Europe); Latin America and the Caribbean (Inter-American Cement Federation [FICEM]), Ibero-American Federation of Ready-Mix Concrete [FIHP]); and Arab countries

[1] The database is operated by a third party (PwC) and based on an internationally recognised reporting protocol, verified and dating back to 2005.

(Arab Union for Cement and Building Materials [AUCBM]), as well as country associations (including in North America, China and India). An Africa Net Zero Concrete Group was launched at COP 27 by the UN High Level Champions and GCCA.

At the cross-industry level, there are several organisations and initiatives which include cement and concrete within their current or planned activities. This includes the Leadership Group for Industry Transition (LeadIT), which includes 18 member countries, as well as 4 cement companies. LeadIT has worked in partnership with GCCA to produce a Green Cement Technology Tracker, to track the latest projects around the world. The recently launched Climate Club includes reference to cement in its Terms of Reference, which were agreed by the G7 in December 2022. The IEA's new Working Party on Industrial Decarbonisation (WPID) also represents a forum for cross-industry collaboration, with 31 country members, plus the European Union.

PRIORITY AREAS FOR INTERNATIONAL COLLABORATION

AGREE COMMON STANDARDS, DEFINITIONS AND GUIDELINES FOR CEMENT AND CONCRETE PRODUCTION AND USE

OVERVIEW

Standards are a vital tool for aligning expectations as to the pace and trajectory of the net zero transition in the cement sector, and for use in different mechanisms that can help enable the transition. A common emissions accounting methodology (or at minimum, an interoperable set of methodologies) is an important first step, working via well-established bodies, such as the International Organization for Standardization (ISO). While cement is not currently highly traded (less than 5% of global production is traded internationally), international collaboration on standards, definitions and guidelines will be important for aligning on the emissions reduction potential of different approaches and technologies, as well as developing and sharing best practice guidance, and reducing administrative barriers for companies operating internationally. There is also the potential for intermediate products that have a higher value-to-weight ratio than cement, such as clinker, to be more highly traded than final products, meaning it will be important for them to be covered by international co-operation on standards.

WHAT PROGRESS HAS BEEN MADE?

Existing international emission accounting methodologies for cement and concrete *production* include ISO 19694 part 3 and the GCCA's CO_2 and Energy Protocol, which are already aligned. An update for novel technologies, such as CCUS, calcined clays and new fuels such as hydrogen, is already underway with the GCCA having started work in this area in 2022.

The carbon footprint of *products* can be calculated and communicated as part of an Environmental Product Declaration (EPD). EPD standards have been developed over a

number of decades and there is close alignment for many parts of the world under EN 15804 (the European Standards body), albeit with local interpretation and application of Product Category rules (PCRs). There currently exists a distinct difference between EN 15804 and the various cement and concrete PCRs that comply with this standard and the approach being taken in North America. IDDI currently has a work programme to provide guidelines for developing and harmonising EPD and PCR standards.

Beyond emissions accounting, establishing definitions for what constitutes low and/or near-zero emission cement and concrete would enable supporting mechanisms that can further advance the transition. Common definitions would allow buyers to differentiate between higher and lower emission products and make it possible for producers to charge a green premium in return for their investments, as well as providing a basis for differentiating subsidy or regulatory policies. Current proposals for definitions include those of the IEA (as endorsed by the G7 in the 2022 Communiqué), FMC, Concrete Zero, the US General Services Administration (GSA) Buy Clean and Buy Clean California. IDDI is currently developing low-emission and near-zero definitions for cement and concrete, building on the IEA methodology. These proposals all differ slightly and would benefit from greater convergence in approach and level of ambition to avoid the emergence of multiple definitions and so reduce complexity for consumers.

Importantly for the sector, improved standards and guidelines for net zero-compatible clinker, cement, concrete and building material use and reuse will also be necessary to help guide project-level decision-making that can improve material efficiency. Design, use and reuse strategies that make more efficient use of cement and concrete have the potential to substantially reduce the sector's emissions, with immediate action possible in lead projects which can be replicated industry-wide, supported by standards and guidelines.

While international collaboration on cement and concrete definitions has received less attention than other more highly traded materials (e.g. steel and aluminium) some forums are emerging which could facilitate such conversations. This includes IDDI, established in 2021, with a membership that now includes India, the United States, Brazil, Saudi Arabia, Japan, Germany, the United Arab Emirates, Canada, the United Kingdom, and Sweden (in order of production), representing about 16% of global cement demand (increasing from 11% last year). These efforts will likely reference and draw on the existing efforts on EPDs, reducing duplication. IDDI is also supporting its members in signing up to a green procurement pledge, which draws on its work on standards and definitions, which will be covered in the next section. The IEA's WPID represents another forum where such agreement could take place. The Working Party currently has 31 country members, plus the European Union, accounting for 14% of global cement production.

WHAT MORE NEEDS TO BE DONE?

There is a need to build stronger international consensus towards the interoperability of measurement methodologies and definitions for near-zero emissions cement, to enable the translation of net zero principles into policy. Countries could work towards this through the IDDI and WPID. Countries working together in these initiatives will also need to collaborate

closely with leading industry players along the cement and concrete supply chain, to understand how definitions and standards can be adopted[2] in different jurisdictions.

> RECOMMENDATION C1:
>
> Countries and companies should work through existing collaborative forums to agree definitions for low and near-zero emission cement and concrete by the mid-2020s, as well as guidelines for the efficient use and reuse of building material

RAPIDLY SCALE UP HIGH-QUALITY DEMAND COMMITMENTS FOR NEAR-ZERO EMISSION CEMENT AND CONCRETE

OVERVIEW

For new near-zero emission cement production, significant capital investments are needed either in the construction of new plants, or in the substantial retrofitting of existing plants. A commercial-scale cement CCUS plant is likely to have a cost of capture of between USD 60-120 per tonne of CO_2. Cement and concrete companies are unlikely to be able to cover such large additional costs at the scale needed unless they have high confidence in there being sufficient demand for the near-zero emission product. Moreover, companies would need to cover increased operating costs for CCUS related to energy consumption and CO_2 transport and storage.

There is a clear opportunity for international collaboration on scaling up demand: the more public and private sector consumers align their actions, jointly creating a stronger demand signal than any of them could individually, the greater the incentives for industry to invest. Different mechanisms to support demand creation for near-zero emission cement include direct offtake agreements as part of public or private procurement, quotas, tax incentives, labelling or CCFDs.

WHAT PROGRESS HAS BEEN MADE?

Commitments from public and private cement buyers have started to gain momentum since 2022. Estimates suggest that the public sector typically accounts for approximately 40% of final cement demand, although this varies significantly between countries. In the private sector, existing commitments include arrangements between the leading cement and

[2] Adoption refers to the requirement for companies to meet such standards in certain government policies, such as procurement, access to finance, subsidy, or regulations.

concrete producers and a range of buyers from across buildings, construction and infrastructure. Cement and concrete often represent a minor share of the final value of their main end-use products, such as buildings, so a relatively large cost increase in each tonne of production translates into a small cost increase at the final product level, often less than 1%.

The main collaborative forums driving action in this area include IDDI, FMC and ConcreteZero. The work of IDDI on standards is introduced above, although the main focus of the initiative is driving an increase in green public procurement (GPP). Countries participating in the initiative aim to make use of technical assistance from international experts, working on elements of the data, standards and procurement policy required, motivated by an overarching political commitment in the GPP Pledge. If all IDDI members were to sign up to at least the third level of ambition under the pledge – which requires countries to commit to the procurement of low-emission cement, concrete and steel in public construction projects from 2030 – it could result in the creation of a market of up to about 330 Mt of low-emission cement by 2030 (assuming all cement covered by public procurement was included). This is nearly equivalent to the approximately 350 Mt of 'near-zero emission' cement required by 2030 under a net zero scenario, although additional 'low-emission' cement would also be needed in that scenario in 2030. The effect of the pledge will depend greatly on the quality of countries' commitments, in terms of what ambition is chosen within the range of bands possible for low emissions cement (the most ambitious band range possible would get relatively close to reaching near-zero emission levels). When committing to the different levels of pledge, member countries should, as far as possible, specify the amounts of near-zero emission cement being targeted and the processes through which these will be procured, to provide a clearer signal on the scale of the market. Further countries joining these efforts could help increase the signal for investment as well as the emissions reduction achieved.

The FMC launched a commitment for cement and concrete at COP 27, with members committing to purchase volumes (at least 10% of their demand) of near-zero emission cement or concrete by 2030. To date, just seven companies have signed up to the FMC cement and concrete commitment. ConcreteZero was also launched in 2022 and already has 32 members (albeit with a strong United Kingdom focus), who have made a commitment to using 100% net zero concrete by 2050, as well as 30% low-emission concrete by 2025 and 50% by 2030. These private sector initiatives are at a relatively early stage, and an increase in membership will be vital to cover a meaningful scale of cement and concrete demand across multiple regions. The level of ambition of these commitments – recognising their different target outcomes – seems relatively high given the stage of technological maturity and cost premium for low and near-zero emission cement production. However, these commitments alone would struggle to deliver the 8% of global near-zero emission cement capacity required by 2030 under the IEA Net Zero Emissions by 2050 Scenario (NZE Scenario).

WHAT MORE NEEDS TO BE DONE?

Countries' discussions within IDDI need to be converted into action, with clear commitments for near-zero emission cement and concrete in public procurement by 2030. More countries and companies should join such demand-creation initiatives, to strengthen their effect.

As in other sectors, the quality of the commitments in these initiatives is as important as the quantity. Cement producers will need legally enforceable, multi-year commitments from buyers, supported by the methodologies and standards covered in the previous section. This means moving from pledges and commitments to policies, regulations and contracts. Greater co-ordination between producers and buyers, whereby leading companies drive a faster understanding of what is possible, can provide a blueprint for the wider market and a supportive government policy. This includes designing procurement guidelines and mandates, relating these to emerging definitions and standards, and establishing reliable near-zero emission supply chains.

Governments should complement purchase commitments with other measures to increase demand. Examples of such measures that are under consideration include Germany's recently launched preparation process for its CCFD policy to support low-emission industrial production, and the United Kingdom's consultation on CO_2 intensity-based mandatory standards. Sharing experience and best practices among countries – such as through the IDDI, the Climate Club, the IEA's WPID and LeadIT – could help others learn from pertinent early policy efforts and help accelerate development of relevant policy tools in a wider range of regions.

RECOMMENDATION C2:

Countries and companies should work through existing collaborative forums to co-ordinate and scale up early efforts to create a market for near-zero emission cement, including via high-quality, multi-year purchase commitments and/or policy support.

FACILITATE PRIVATE SECTOR COLLABORATION ON NOVEL TECHNOLOGIES, USING PUBLIC SUPPORT TO DRIVE COST REDUCTIONS IN ALL REGIONS

OVERVIEW

Novel technologies are urgently needed to reduce emissions from the production of cement. Emissions from the production of cement can be divided into energy-related emissions associated with heating kilns and use of processing equipment, and the process emissions associated with the calcination of limestone, the primary input to most cement today. Energy-related emissions typically account for about one-third of total CO_2 from cement production, with process emissions accounting for the remaining two-thirds.

Most of the key technologies required for near-zero emission cement production have not yet been deployed commercially at scale. The most advanced technology that can achieve >90% emission reduction is CCUS. At high capture rates, this technology is currently at technology readiness level[3] (TRL) 7, with pre-commercial demonstrations at various stage of development for calcium looping, chemical absorption and direct separation technologies. Physical adsorption, oxyfuelling and cryogenic capture are also being piloted (TRL 5-6), while other more novel forms of carbon capture, such as membrane separation, are at earlier stages of development, at TRL 4.

Research into production routes for lower emission cement that may not require CCUS is also ongoing. Some use alternative raw materials that result in reduced or no process CO_2, in the form of clinker, alternative binders or supplementary cementitious materials (e.g. calcined clay), and include projects from Brimstone, Solidia Technologies and Terra CO_2, among many others (TRL 3 – 8). Only some of these – which are not yet commercially available – would fully eliminate process emissions and thus be considered near-zero emission cement. Another technology that could eliminate process emissions is the use of electrolyser-based processes for decarbonating calcium carbonate prior to clinker production, which is being explored by projects such as Sublime (TRL 3). Other projects are looking to decarbonise combustion emissions, such as through cement kiln electrification (CemZero) or a solar thermal calciner (CEMEX/ SynHelion), although to achieve near-zero emissions these would need to also be paired with CCUS to address process emissions.

WHAT PROGRESS HAS BEEN MADE?

There has been a wave of recent announcements of commercial-scale projects, which are largely focused on CCUS, alongside some earlier stage feasibility studies and demonstration plants that are exploring other non-CCUS routes. To date, there are 14

[3] Technology readiness level (TRL) refers to the current stage of maturity for a given technology solution, ranging from an initial idea or concept to commercial-scale operation.

commercial-scale near-zero emission cement plants planned (with none yet in operation), all of which plan to use carbon capture with dedicated storage and all of which are in Europe and North America. Several pilot and demonstration scale projects are also underway or planned in other countries such as China, Australia, India, and Japan, although the vast majority of activity is in Europe and North America.

While the growing pipeline of announcements to build plants is a positive sign, the first few operational commercial-scale plants are urgently needed to facilitate learning and practice with these as-yet untested technologies. There is a clear opportunity for international collaboration: if countries and companies work together to increase the number of plants in which these technologies are deployed and tested, and share findings from these experiences, the learning process can be accelerated across multiple regions in parallel. Moreover, efforts are required to share learning beyond those countries that can afford the currently expensive trial and demonstration of these novel technologies with those countries that will have the greatest need for cement and concrete in the coming decades.

In September 2022, the NZIM under Mission Innovation was launched with members representing about 60% of global cement production, with China alone being responsible for approximately 50%. In March 2023, countries participating in this initiative set out an action plan, which includes 'cement and lime' as a key sector and states the intentions of establishing a stakeholder dialogue, designing and implementing frameworks for co-ordinating and accelerating global co-operation, and leveraging existing work.

To support this, the NZIM co-lead countries are working to strengthen collaborative relationships between its members. This includes an initial call for Expressions of Interest from two countries in NZIM during 2023 to help facilitate deeper knowledge-sharing among countries and companies.[4] If proven to be a successful model for strengthened collaboration, such a process could be repeated across more of NZIM's members, with key outcomes communicated to other members.

In 2020, the GCCA launched its research network, Innovandi, which brings together over 40 academic institutions and industry (including 34 cement and concrete manufacturers, admixture companies, equipment and technology suppliers) to collaborate on pre-competitive research. Companies in this initiative are currently delivering 12 core projects, involving 30 PhD programmes, on issues such as the use of calcined clays, electrified cement production and artificial intelligence-driven energy use optimisation. Whilst the breadth of topics covered by this collaboration is impressive, a greater focus on projects that can deliver near-zero emission production will help accelerate the development and deployment of those technologies that can make the most difference. In addition, 62 partner projects have been accepted into the network, of which 19 have been finalised, enabling

significant international collaboration on a wide range of topics that will be important for the sector's decarbonisation. The network covers a range of both advanced and emerging economies.

[4] Further information to be made public later this year.

WHAT MORE NEEDS TO BE DONE?

Private sector collaboration in the sector appears to be progressing well, while collaboration between governments is at an earlier stage. It will be important for countries in NZIM to quickly agree modalities for sharing learning between its participant countries (and others, if possible) so that the lessons from the first wave of pilot near-zero emission cement production plants can be widely shared and can contribute to improvements in technology and plant design.

It is also important to involve more developing countries in these initiatives. Developing countries are expected to account for most of the growth in global cement demand in the coming decades, and given the high cost of transporting cement, much of this demand is likely to be met through domestic production. Paired with an improved technical and financial assistance offer (see next section), a concerted effort to include developing countries in collaborative R&D initiatives, and to share experience from novel projects more rapidly, could help avoid significant emissions lock-in. These should take into account local variability, including access to carbon storage and alternative cementitious materials.

> RECOMMENDATION C3:
>
> Countries should work together with effective private sector collaborative forums to accelerate the pace of learning between a wider set of countries, with a particular focus on developing countries. These partnerships should support the delivery of pilot and demonstration scale projects in all major emerging and developing countries well in advance of 2030.

IMPROVE THE CO-ORDINATION OF ASSISTANCE PROGRAMMES FOR COMMERCIAL-SCALE PROJECTS IN DEVELOPING COUNTRIES

OVERVIEW

The transition in the cement sector will need strong support from policy and, as in other sectors, international assistance, finance and the sharing of best practice can help to enable the necessary policy measures. Eight of the current top ten cement-producing countries are emerging economies, making deployment of near-zero emission technologies in these regions a global priority. Emerging economies are also likely to be responsible for over 85% of global cement production in the coming decades, implying that their policy choices will have a significant influence on the global market.

WHAT PROGRESS HAS BEEN MADE?

At present, there is an extremely low level of financial support being provided to emerging economies to aid the transition from conventional cement-producing technologies to low-emission alternatives. Of the major international financial institutions (IFIs), only the International Finance Corporation (IFC), the European Bank for Reconstruction and Development (EBRD), the World Bank and the Climate Investment Funds (CIF) have existing programmes or projects that support cement decarbonisation. These mainly support increasing the efficiency of high-emissions cement production, rather than the introduction of near-zero emission production methods, technologies and infrastructure. The CIF Industry Decarbonization Program was announced at COP 27 with an initial USD 80 million (out of a target of USD 500 million), although a timeline for supporting initial projects is yet to be finalised.

WHAT MORE NEEDS TO BE DONE?

There is a clear need for stronger international efforts in this area. Emerging economies will require significant levels of investment to enable the transition to near-zero emission cement production, including supporting infrastructure. The majority of this will come from private sources, as the role of public funds here is primarily to de-risk investments, helping to mobilise larger-scale private finance, rather than to cover the entire cost of a new plant. However, for the first plants – including first-of-a-kind commercial-scale facilities – public finance will be a vital enabler to cover the green premium and help mobilise further private capital. International assistance can help with policy design and project development.

As has become clear in the steel industry and other sectors, as international funds are mobilised to support early efforts, it will be increasingly valuable for countries and other development partners to work together on the successful delivery of projects and associated policy measures, in line with developing country needs. Building a new community of practice among key stakeholders for cement decarbonisation is challenging given that financial and technical assistance for industrial decarbonisation typically cuts across multiple different sectors. Including cement within the remit of a forum that matches countries' demands for assistance with the supply of assistance from the international community, as we recommend in the steel chapter, could have important benefits.

Such a matchmaking function should include the identification of appropriate funds and the technical assistance to support the deployment of near-zero emission technologies, and dialogue on the policy measures that can make those technologies commercially viable and attract private investment. The platform can aggregate expert advice and in-country experience to provide guidelines on those projects and policy measures that can best advance the transition, taking regional variability into account.

RECOMMENDATION C4:

Countries should establish a matchmaking function focused on industry decarbonisation and cement that can better respond to developing country requests for financial and technical assistance. In addition to participating countries, this should include IFIs, national development banks, philanthropic organisations, private financial institutions, industry coalitions and companies, with regular meeting of ministers.

RECOMMENDED REPORTS

We recommend the following reports for more detailed descriptions of the technologies for cement sector decarbonisation and of the actions that countries and businesses can take individually.

Reaching Zero with Renewables: Eliminating CO_2 emissions from industry and transport in line with the 1.5ºC climate goal (IRENA, 2020)

Concrete Future – GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete (GCCA, 2021)

Achieving Net Zero Heavy Industry Sectors in G7 Members (IEA, 2022)

Making Net-Zero Concrete and Cement Possible (MPP, 2023) [forthcoming]

CHAPTER 8. AGRICULTURE

STATE OF THE TRANSITION

The Breakthrough objective for the food and agriculture sector, as adopted by signatory countries at COP 26, is that climate-resilient, sustainable agriculture must be the most attractive and widely adopted option for farmers everywhere by 2030.

Agriculture accounts for around one-third of all GHG emissions globally when food production, transport, processing, retailing, and loss and waste along the entire value chain are considered. Almost half of the world's population lives in households reliant on agrifood systems for livelihoods. The agrifood sector is particularly vulnerable to climate change, with losses and damages occurring throughout the value chain due to extreme weather events like high temperatures, droughts and floods. Small-scale farmers in the Global South are especially at risk, and current efforts to adapt to climate change fall short of what is needed. Further, without sustained reductions in emissions in this sector, international climate goals cannot be met.

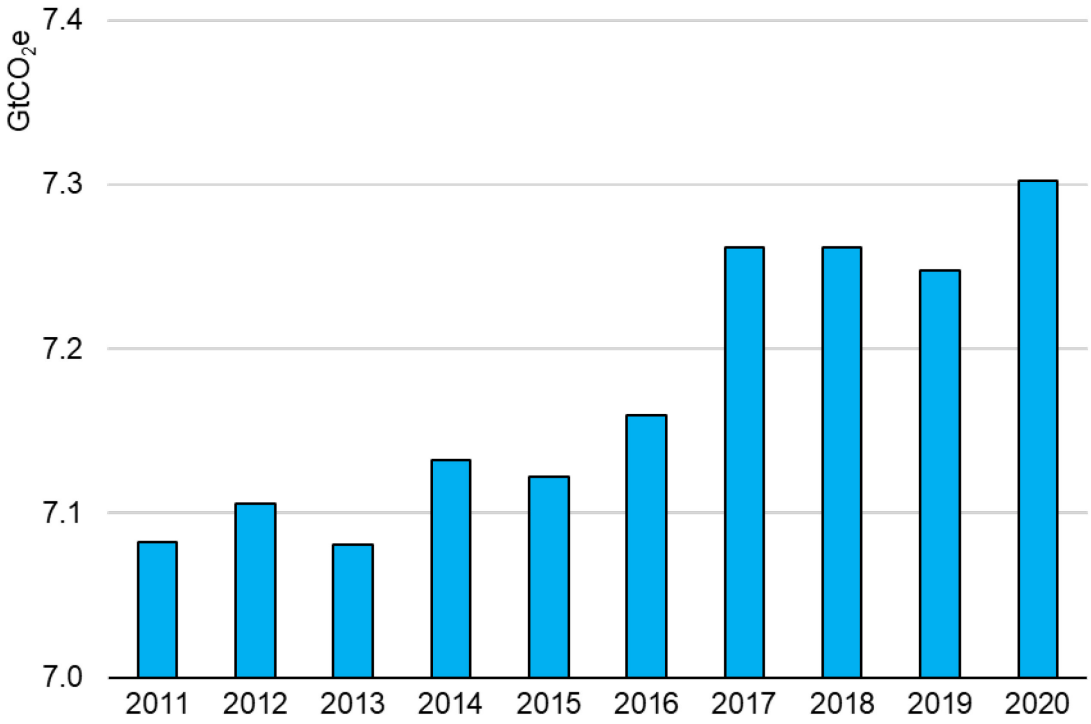
The agrifood sector requires transformative changes (or breakthroughs) within a just transition framework. It needs to reduce emissions and ensure food and nutrition security without endangering the livelihoods of smallholder producers or damaging natural resources. The sector's inherent diversity makes technologies and approaches for reducing GHG emissions and building long-term climate resilience very context-specific. This then requires careful analysis of trade-offs and synergies across various dimensions, in order to choose technologies that minimise trade-offs and maximise synergies. Innovations in practices, technologies,[1] policies and financing across various sub-sectors and components of the agricultural value chain are needed.

In last year's report, we proposed four principles to measure progress against the agriculture breakthrough objective. These were: 1) agricultural productivity and incomes must sustainably increase; 2) GHG emissions from the sector must decline; 3) soil, water, and natural ecosystems should be safeguarded; and 4) the sector as a whole – including the 80% of the world's poor who live in rural areas and work mainly in farming – must adapt and build resilience to climate change.

Unfortunately, very little progress has been achieved in the last 5 years across these dimensions. Global crop yields and metrics for livestock have shown no change over the last years of available data. GHG emissions from agriculture (at farm gate) also show virtually no movement towards the 2030 goal of declining to 5.70 Gt CO_2 equivalent (CO_2-eq), remaining at around 7.25 Gt CO_2-eq from 2016 to 2020 (Figure 8.1).

[1] The term technological areas (or technologies) and approaches is used throughout this chapter to describe different types of innovations i.e. in practices, technologies, strategies, approaches, policies, financing, etc.

Figure 8.1. Agriculture related emissions (at farm gate), 2011-2020



Note: Farm gate emissions include emissions from crop residues and their burning; rice cultivation; enteric fermentation; manure management, including manure left on pastures and manure applied to soils; synthetic fertilisers; and energy use in agriculture.

Source: FAO (2023), FAOSTAT (database), (accessed Sept 2023).

Gains and losses in global cropland have roughly balanced out, but this small net change masks that agricultural expansion continues to drive deforestation globally and particularly in the tropics.[2] Agricultural land expansion globally will have to stop if the global targets for 2030 to end deforestation and to halt the loss of natural vegetation important for biodiversity are to be met. According to the Food and Agriculture Organisation (FAO), agricultural water use efficiency (value of output per m^3 of water used) increased by 12.5 % between 2015 and 2019. FAO also reports, however, that water stress is rising in "critically affected" regions in the Global South. In sum, the most recent year of data collection reveals a fairly uniform lack of progress across the metrics selected in last year's report. While it is true that meaningful observations on agricultural sector trends require longer time horizons, the most recent year's lack of desired movement is consistent with the previous 5 years of slow progress in this sector.

[2] From 2015 to 2022, for example, deforestation occurred across a total of 48 Mha globally, with over 70% of these permanent losses being due to large-scale commodity production (which includes mining, and oil and gas extraction) (Hansen et al., 2013; Curtis et al., 2018; Turubanova, S. et al., 2018; Tyukavina, A. et al., 2022).

In this report we propose modifying the four principles to emphasise the importance of a just transition in this sector in the face of ongoing climate change, while also emphasising the context-specificity of agricultural solutions, as follows:

- Agricultural productivity and incomes in low- and middle-income countries (LMICs) must increase sustainably, in order to achieve food and nutrition security and healthy and sustainable diets for all.
- The sector must reduce GHG emissions, and depending on technologies and approaches and geographies, these can be reductions in emissions intensity, or absolute emissions reductions, or both, with the ultimate aim of reducing absolute emissions.
- Soil, water, biodiversity and natural ecosystems must be safeguarded across all geographies, including through a focus on healthy ecosystems.
- The sector must adapt and build resilience to climate change, including through approaches that promote inclusion and social safety nets for the poor and vulnerable smallholder producers in the Global South.

SEVEN PROMISING TECHNOLOGY AREAS AND APPROACHES CRITICAL TO THE TRANSITION

In last year's report we identified seven technological areas and approaches critical to accelerating the transition in the agriculture sector. These include: reducing emissions from fertilisers; alternative proteins; reducing food loss and waste; crop and livestock breeding; reducing methane emissions from livestock; agroecological and other sustainable approaches; and digital agriculture and climate services.

In this year's report, we consider how international collaboration can accelerate development and deployment of solutions in each of these seven areas.

In each area, many national (and local) actions will be required, as well as international collaboration. Figure 8.2 shows the four (updated) principles, which are the desired outcomes of the agricultural breakthrough; the five pathways, which are ways in which these desired outcomes can be achieved; and the seven technological areas and approaches on which concrete actions need to be taken in order to achieve the desired outcomes. These seven technological areas and approaches are by no means comprehensive, and we also identify a few other technological areas and approaches for inclusion in future reports. Our updated recommendations are based on the priorities emerging from a detailed science-based analysis of the seven technological areas and approaches in an underlying report by the CGIAR titled "Achieving agricultural breakthroughs: A deep dive into seven technological areas and approaches", henceforward called the CGIAR report.

Figure 8.2. Principles and pathways for achieving breakthrough in the agriculture sector

Note: ASF= animal source foods; HIC = High income countries; NUE= nitrogen use efficiency.

This also provides an Illustrative example of how seven technological areas and approaches map onto different pathways for achieving the breakthrough objectives while adhering to the four breakthrough principles. This figure is not meant to be a comprehensive mapping of all seven technological areas and approaches across all five pathways, as objectives for many or most of them can be achieved through multiple pathways. The seven technological areas and approaches covered in this chapter are in boxes with solid lines and are underlined and italicised. New technologies and approaches suggested for inclusion in future reports are in boxes with dotted lines.

Sources: IEA analysis based on data from IEA, IRENA and UN Climate Change High-Level Champions (2022), Breakthrough Agenda Report 2022.

In last year's report, we called for increased levels of climate finance directed at agriculture; a long-term process to share learning on policy reforms; a strategic dialogue on international trade in relation to the agriculture transition; development of agreed standards for monitoring the state of natural resources on which agriculture depends; and higher investment in agricultural RD&D. Metrics to track year-on-year action on these broad recommendations are high level at best, but our latest analysis supports the view that these five broad areas continue to represent the priorities for international collaboration in the sector.

In this chapter we respond to a request from countries under the Agriculture Breakthrough for deeper analysis of the seven technology areas, and increasingly specific recommendations on international collaboration. In each section below, we make a brief assessment of progress against last year's recommendation, followed by new and targeted recommendations for 2023.

INCREASED INTERNATIONAL CLIMATE FINANCE SHOULD BE DIRECTED TO UNLOCKING THE POTENTIAL OF AGRICULTURAL TECHNOLOGIES AND APPROACHES WITH PROVEN EFFECTIVENESS

OVERVIEW

Last year, we recommended that the level of international climate finance directed at agriculture should be greatly increased, in line with its importance to global emissions, adaptation and resilience and food security. We also recommended that governments, multilateral development banks (MDBs) and private sector investors should work together to make finance and assistance available to small- to medium-sized enterprises (SMEs) and smallholder farmers in developing countries on a far larger scale than has been achieved so far.

WHAT PROGRESS HAS BEEN MADE?

We assess that minimal progress has been made against the recommendation we made last year.

Total (international) climate-related development finance (from bilateral, multilateral and private philanthropic sources) to agriculture, forestry and fisheries dropped in 2020/21 versus the previous year[3], with 2021 levels at the lowest seen since 2016. The gap between needed investment and actual flows is large and growing. At an annual average of USD 28.5 billion, agrifood systems receive just 4.3% of total global climate finance tracked

[3] Last year's Breakthrough Agenda Report reported on data for 2019/20.

at the project level (domestic and international combined) and the Climate Policy Initiative (CPI) estimates that seven times as much is needed to meet even the lowest estimates of climate investment needed by the sector.

Some progress has been made in laying the analytical groundwork – to be presented by international organisations around COP 28 – for the recommended increase in climate finance for agrifood systems. International organisations and initiatives across public and private sector actors are producing, for example, a detailed analysis of OECD-Development Assistance Committee (DAC) financial flows and investment gaps in agriculture and food systems (Food and Agriculture for Sustainable Transformation Initiative (FAST)); an analysis of public and private current climate finance flows to agriculture, forestry and other land use (AFOLU) and associated recommendations for private and public actors (Climate Shot Investor Coalition and CPI); and a roadmap to help investors in the sector align their portfolios with the Paris Agreement aim of limiting global warming to 1.5 °C (FAO and the FAIRR Initiative). While these analyses are important, it is vital that a substantial increase in climate finance follows. The UNFCCC report on the second biennial communication, released in the early half of 2023, states that many governments remain committed to maintaining or increasing their current levels of climate finance. The most recent updates on the levels of climate finance that have been disbursed, however, are expected to be released around COP 28 this year. They will show to what extent progress has been made globally and from all sources.

WHAT MORE NEEDS TO BE DONE?

This year's recommendation supplements the headline call for more finance by focusing on specific financing gaps that need to be closed to support the rapid deployment of solutions that have been proven to be effective, while reducing emissions and/or enabling adaptation.[4] We suggest the following areas as priorities for international climate finance in the agriculture sector, based on their significance for global emissions and the availability of scalable solutions:

- **Agroecology:** Incremental climate finance should be added to ongoing streams of development finance in order to support greater integration of agroecological and other sustainable approaches in farming and food systems (i.e. that increase ecological functioning and enhance carbon storage and sequestration, while also strengthening resilience to shocks[5]). Such approaches reduce GHG emissions, improve food security and achieve environmental outcomes. This incremental finance should be accompanied by robust economic and financial viability analysis for the specific context of projects and programmes. A review of evidence on biodiversity restoration,

[4] Technologies and solutions can be organised by technology readiness levels (TRLs), ranging from an idea all the way to full commercialisation, under all uncontrolled conditions. This recommendation targets innovations for which there is scientific evidence of effectiveness. Those that are more less developed can be found across all technology areas in the CGIAR report. Other innovations may already have reached niche markets (e.g. some newer alternative proteins), and the support they need is highlighted in other recommendations below.
[5] For more information, see section 7 the CGIAR Report.

mitigation and adaptation co-benefits, food security, and improved livelihoods, as well as on the pattern of productivity gains, losses and sustained recovery is provided in section 7 of the CGIAR report. International partners should also co-ordinate around instruments that target financial support to offset any temporary losses (if needed) to producers who are making the transition to agroecology and other sustainable approaches. This will be particularly important for small-scale producers, as will developing links to markets for agroecological and other sustainable products, backed by robust risk analysis and publicly supported risk instruments.

- **Reduction of food loss and waste** can be mainstreamed into all investments in food systems, including those supported by international development assistance. Proven technologies to reduce loss and waste along the value chain include reducing food losses at the production and postharvest stage, particularly in the LMICs where such losses are high, and reducing food waste at the consumer level, particularly in HIC contexts where such waste tends to be high.[6] At the global level, halving food loss and waste can potentially remove 25% of GHG emissions from the food system.
- **Reducing methane emissions from livestock**: Proven methane-reducing technologies in the livestock sector include methane inhibitors such as 3-nitrooxypropanol (3-NOP), tanniferous forages as feed additives, concentrate feeds, and anaerobic digesters (ADs) that break down manure. In Africa, over 100 000 such ADs are currently operational on farms, while China and India combined have over 40 million. International financial assistance can help to rapidly increase the use of all these technologies, by making them more affordable. In addition, for LMICs, simply increasing financing for the mainstreaming of climate smart livestock approaches that improve livestock productivity will have a significant impact not just on emissions but also on livelihoods.[7]
- **Reducing emissions from fertilisers:** Technologies that reduce emissions from fertilisers while maintaining positive productivity include slow-release fertiliser, chemical and biological inhibitors and coated fertilisers; precision nutrient management such as sensor-based fertiliser management, and use of decision support systems for fertiliser recommendations. The production of alternative fertiliser has not yet achieved significant scale, meaning that economic viability versus conventional fertiliser is likely to remain an issue until increased uptake drives costs down.[8] The same type of early-stage public finance that has supported demonstration projects, or technical assistance for policy reforms for alternative energy technologies, could be used to support the market development and deployment of alternative fertilisers.
- **Crop and livestock breeding**: Successful crop and livestock breeding outcomes, i.e. technologies that raise both the productivity and climate resilience of crops and

[6] See section 4 of the CGIAR report for reviews of these technologies.
[7] See section 6 in the CGIAR Report.
[8] See also section 2 in the CGIAR report.

livestock, have been robustly tested. Countries and MDBs providing international development assistance, co-ordinating internationally with leading research and breeding organisations, can target funding to enable crop and livestock breeders and scientists in developing countries to access new high-precision breeding equipment and capacity, and can support the diffusion of successful approaches. In the context of livestock breeding, animal health and welfare should be given utmost importance. Any unintended consequences and trade-offs for animal welfare and health should be mitigated to prevent reduction in animal fitness resulting from selection for high productivity traits.[9]

Across the seven technology areas, the lack of capacity and know-how regarding improved technologies will slow adoption. It will be important to support capacity building and technical assistance to developing country governments in each of these areas.

RECOMMENDATION A1 HAS BEEN UPDATED AS FOLLOWS:

Increased climate finance should be directed to supporting the deployment of agricultural technologies and approaches for which science has generated evidence on effectiveness, including agroecology, reducing food loss and wate, reducing livestock methane emissions, reducing emissions from fertilisers, and crop and livestock breeding

PROMOTE INTERNATIONAL SHARING OF KNOWLEDGE ON POLICY AND IMPLEMENTATION TO FACILITATE FASTER UPTAKE OF PROVEN TECHNOLOGIES

OVERVIEW

Last year we recommended that governments, research institutions, international organisations and the private sector should commit to a long-term process to test, develop evidence, and share learning on approaches to redirecting policies and support for agriculture towards sustainability and climate resilience. we specified that this should involve all the world's largest agricultural producer countries, whose policies heavily influence global markets, as well as countries representing a diverse range of environmental and economic conditions.

[9] See section 5 in the CGIAR report.

WHAT PROGRESS HAS BEEN MADE?

We assess that modest progress has been made against the recommendation we made last year.

The Policy Dialogue on Transition to Sustainable Agriculture, co-convened by the United Kingdom and the World Bank, was launched in January 2021 and provides an on-going active – primarily intergovernmental – platform for peer-to-peer experience-sharing, knowledge exchange and building collective ambition for policy reform. The 26 countries participating in this initiative comprise LMIC and HIC nations from across multiple regions, but so far include only 2 of the world's top 10 agricultural producers.

There have been ongoing efforts towards developing complementary international dialogue for a wider set of participants, such as the Just Rural Transition initiative that brings together producers, civil society, the private sector and others. While not yet a long-term process, there have been further episodic initiatives, such as the Africa Agriculture Policy Leadership Dialogue in 2023, that have convened similar discussions with a wider set of actors from the private sector, international organisations and research communities. Other international efforts include the policy side events held at the UN Food System Summit Stocktake in 2023.

WHAT MORE NEEDS TO BE DONE?

To meet international climate goals, rapid knowledge-sharing on best practices in policy and implementation is urgently needed. This will help avoid "reinventing the wheel" in regions that are at an earlier stage in their transition. We identify key areas where international knowledge sharing is critical to support a "just rural transition" to sustainable food systems, focusing on those technology areas for which an absence of strong international knowledge networks or a dearth of shared policy experience are key obstacles to the uptake of innovation and the spread of new solutions.

While there has been an increase in attention and intention around platforms for international collaboration on sharing best-practice policies and approaches, equally important will be the identification of a priority, science-based agenda for these platforms; the participation of countries that together make up the majority of relevant global markets; the provision of high-quality evidence and analysis to inform discussions; and the long-term funding and political commitment to enable exchanges to be sustained over time.

We judge that leveraging, strengthening and – where necessary – creating international knowledge networks closely linked to national-level agencies will be important for more widespread implementation of solutions in the following areas:

- **Alternative proteins**: There is a need to develop knowledge exchange platforms on the regulatory frameworks and policies to promote the use of newer alternative proteins.[10]
- **Reducing food loss and waste:** The FAO, World Resources Institute (WRI), One Planet, and Meeting of Agricultural Chief Scientists-G20 Collaboration Initiative, among others, with the support of CGIAR, can provide co-ordinated and increased technical assistance and data to existing multi-stakeholder platforms currently promoting dialogues among researchers, industry, governments and civil society on the needs and means to reduce food loss and waste.[11] Countries can also share best practice in conducting consumer awareness campaigns to reduce food loss and waste, supported by international partnerships such as One Planet's Sustainable Food Systems (SFS) Programme and FAO's SAVE FOOD: Global Initiative on Food Loss and Waste Reduction.
- **Reducing methane emissions from livestock:** National government ministries and industry leaders should engage substantively in sharing knowledge, with the support of key international research initiatives and organisations[12], to further scale up innovative technical solutions for reducing methane emissions and/or climate-smart livestock production practices that also improve livestock productivity and livelihoods – particularly for smallholder producers in LMICs.[13]
- **Digital services:** Digital services in agriculture can help farmers and small agricultural businesses to rapidly gain the skills and knowledge they need to adapt to and mitigate climate change while improving food production sustainably in several ways. Greater support for regional associations that raise awareness, inter-country co-operation, and knowledge sharing that is aimed at ensuring poor people, women and youth have good access to mobile internet and cellular services should be provided. This can be supported through sharing international experience on public-private partnership investments for affordable digital agriculture and climate services, and through more funding to these regional associations.[14]
- **Repurposing agricultural support and subsidy policies** from existing distortionary agricultural support that encourages pollution and environmental degradation towards more climate friendly incentive regimes. The need to repurpose existing agricultural policies and subsidies to support more sustainable practices is a common theme that runs through all seven technology areas. Current support to agriculture, provided through public policies and expenditures, is sizeable. Of the overall annual support by a group of 79 countries, estimated at USD 638 billion, about 70% (or USD 431 billion)

[10] See section 3.6 of the CGIAR report.
[11] See section 4.6 of the CGIAR report.
[12] Key international research institutes in this field include the Global Research Alliance on Agricultural Greenhouse Gases (GRA), CGIAR, the Global Methane Hub, and the WRI.
[13] See section 6.6 of the CGIAR report.
[14] See section 8.6 of the CGIAR report.

is directly targeted at producers.[15] Of this direct producer support, about 86% is through measures that the OECD refers to as "potentially most distorting"—including both market price distortions as a result of policies, and explicit subsidies as fiscal expenditures. The remaining 14% is in the form of decoupled transfers, which are less distorting. The distortive effects of many of these subsidies – including their role in raising GHG emissions – is well understood, as is the need, therefore, to repurpose them. Countries should participate in initiatives designed to share knowledge on reorienting agricultural policy support, such as the Policy Dialogue on Transition to Sustainable Agriculture.[16] They should work together through such initiatives to formulate indicative pathways for policy action, including repurposing agricultural subsidies towards incentives and support for capacity-building and uptake of sustainable agriculture practices and technologies highlighted in Recommendation 1. These technologies include low-emission fertilisers, food loss and waste reduction across entire value chains, investments for the appropriate implementation of agroecological and other sustainable approaches, proven methane-reducing technologies and climate-smart practices in livestock, and incentives towards greater international collaboration on crop and livestock breeding.

Further to the work on repurposing of subsidies, there is a dearth of shared policy experience on key areas such as agroecology and digital services. Specifically, key international organisations such as the United National Environment Programme (UNEP), FAO, The Nature Conservancy, Biovision, Agroecological Coalition and the Transformative Partnership Platform (TPP)[17] should document and disseminate policy experience and regulatory best practice to strengthen policy and institutional frameworks needed for uptake of agroecological and other sustainable approaches, which can be then taken up by governments. Governments should ensure that these, and other robust evidence bases underpin the platform agendas in which they participate. Similarly, the Global Coalition for Data and Digital Food Systems Innovation should work with the FAO[18] to create evidence to inform policy coherence and demonstrate the need for affordable digital services that are gender-aware and inclusive in agriculture. Governments should actively engage with these research outputs in their digital services investments.

[15] The remainder going to expenditures on public goods and services such as R&D, support to consumers, and small share explicitly targeted at promoting sustainable practices, such as land set-aside programmes.
[16] In addition to the Policy Dialogue on Transition to Sustainable Agriculture, international organisations engaged actively in policy and investment dialogues should bring the international best practice policy experience to the implementation of these recommendations (see Table 9.1 in the CGIAR Report for full list of possible partners who could implement recommendations).
[17] See section 7.6 of the CGIAR Report.
[18] See section 8.6 of the CGIAR Report.

RECOMMENDATION A2 HAS BEEN UPDATED AS FOLLOWS:

Governments, research institutions, international organisations and the private sector should commit to a long-term process to test, develop evidence and share learning on policy and implementation. This should prioritise the redirecting of subsidies to support agriculture to move towards sustainability and climate resilience, and the facilitation of faster uptake of proven technologies in the sector.

DEVELOP COMMON METRICS AND INDICATORS TO TRACK THE ADOPTION OF SUSTAINABLE AGRICULTURE SOLUTIONS

OVERVIEW

Last year we recommended that countries and international organisations should develop internationally agreed standards for monitoring and reporting on the state of natural resources on which agriculture depends, including soil carbon content and health, and pollinator health, as well as on the geographical extent of agriculture. We reported that there was a lack of regularly updated internationally comparable data on the extent of agricultural land, soil carbon, and biodiversity and pollinator health. We noted that such metrics are essential to support an understanding of the extent to which agricultural practices intended to be sustainable actually are sustainable, and that international measurement standards would help support high-quality knowledge sharing on policy effectiveness and enable international trade to play a positive role in supporting the transition.

WHAT PROGRESS HAS BEEN MADE?

We assess that minimal progress has been made against the recommendation we made last year.

While some international discussions on these issues continue to take place, there are still no agreed common metrics for tracking these indicators. For instance, there are regional agreements across subsets of countries on soil health (e.g. within the European Union), but despite the plethora of available soil health monitoring frameworks and indicators, there is no consensus on their use globally.

WHAT MORE NEEDS TO BE DONE?

There remains a need for countries and international organisations to develop internationally agreed standards for monitoring and reporting on the state of natural

resources on which agriculture depends. These include soil carbon content and health, pollinator health, and the geographical extent of agriculture.

In addition, we find that there is a need for internationally agreed metrics to track the adoption of some of the key sustainable agriculture solutions identified in this report. This could help inform the targeting of international assistance, and support the adoption of co-ordinated policy measures, as well as facilitate trade (see Recommendation A5). The technology areas and approaches that are not accurately tracked at present – and therefore for which it is not possible to assess progress – include reducing livestock emissions, reducing food loss and waste, increasing equitable access to digital agriculture and climate services, increasing impact evidence for the integration of agroecology and other sustainable approaches, and documenting environmental and health outcomes for new alternative proteins. To fill these gaps, countries and international organisations should work together on the following priorities:

- Reaching international agreement on metrics, measurement and reporting methodologies for livestock enteric methane emissions. This would permit the development of targets and baselines for such reductions.[19]
- Based on existing protocols, reaching agreement on the common adoption of globally consistent measurements for tracking food loss and waste. This would provide accurate data for tracking hot spots for food loss and waste – globally, nationally and locally – and to inform national and international development investment decisions in support of greater mainstreaming of measures to reduce food loss and waste. Detailed annual estimates should include data on nutrient losses along the food supply chain to inform food security interventions.[20]
- Agreeing internationally on metrics for examining the performance of agroecology and other sustainable approaches (including climate smart agriculture and regenerative agriculture) to provide decision makers and would-be investors with accurate data.[21]
- Developing common metrics and indicators to monitor progress in connecting to smallholder producers through digital services will inform technical support for governments and private sector start-ups and help ensure equitable digital agriculture and climate services for all.[22]

[19] See section 4.6 in the CGIAR report.
[20] See section 4.6 in the CGIAR report.
[21] See sections 7.3 and 7.6 in the CGIAR report.
[22] See section 8.6 in the CGIAR report.

RECOMMENDATION A3 HAS BEEN UPDATED AS FOLLOWS:

Governments, international organisations and research institutes should develop common metrics and indicators to track the adoption of key sustainable agriculture solutions and to monitor the state of natural resources on which agriculture depends.

INCREASE SUPPORT TO FOOD SYSTEM RESEARCH, DEVELOPMENT AND DEMONSTRATION TO SUPPORT UPTAKE AND SCALING OF PROMISING TECHNOLOGIES AND APPROACHES

OVERVIEW

Last year we recommended that governments and companies should work together to deliver higher levels of investment in agricultural research, development, and demonstration (RD&D), to be maintained over the course of this decade. The scale and diversity of collaborative international RD&D initiatives and programmes should also be increased. Priority should be given to innovations that can reduce food waste, limit emissions from livestock and fertilisers, improve alternative proteins, develop climate-resilient crops and livestock, and protect soil and water resources.

WHAT PROGRESS HAS BEEN MADE?

We assess that modest progress has been made against the recommendation we made last year.

Last year we reported that the level of funding for agricultural research had fallen in recent years, especially from high income countries. We noted that this was weakening collaborative international efforts, with an example being that spending through the CGIAR on agricultural R&D in 2019 was 30% below its inflation-adjusted level in 2014. Since then, there has been an 11% nominal increase in funding to the CGIAR, but this can only be loosely indicative of the level of support for collaborative international efforts, which are a subset of overall food system RD&D. Unfortunately, detailed annual breakdowns on the sources and uses of all relevant RD&D investment globally are not found to be easily accessible on a year-on-year basis.

This year, however, has seen an uptick in dollar commitments through the Agriculture Innovation Mission for Climate (AIM4C), a key global forum for collaboration between governments and other partners to mobilise greater investment in climate-smart agriculture R&D. AIM4C government members raised their commitments this year to just over

USD 10 billion for the 2021-2025 period across 5 priority areas. The Innovation Sprints undertaken to date map to most of the technological innovation areas identified by the Breakthrough Report, with the notable exception of food loss and waste. While this initiative is welcome and well aligned with the priority technological areas independently identified by this report, both more funding and research projects are needed to fill the priority gaps remaining (see below).

WHAT MORE NEEDS TO BE DONE?

Investment in RD&D and the adoption of climate relevant technologies and approaches for use in low- and middle-income countries (LMICs) has an estimated potential of reducing agriculture, forest and land use emissions by some 40-50%. This finding covers both the increased uptake of innovation and the continued importance of discovery science in identifying the transformation solutions of the future.

Last year we identified a set of technology areas as having RD&D gaps that needed to be filled to "accelerate the development and eventual cost-effective deployment of technologies and solutions" to reduce emissions and improve resilience. Here we highlight a number of specific RD&D gaps within each of these technology areas (see the CGIAR report for full details) and recommend how they may be overcome:

- **Reducing methane emissions from livestock:** Further studies are needed to assess the specific on-farm mitigation potential and impacts of different methane emission reducing strategies and technologies in the livestock sector in diverse regions and farming systems. In addition, investing in RD&D to identify cost-effective methods for Measurement, Reporting, and Verification (MRV) of emissions reductions in the livestock sector could lead to greater carbon market opportunities, including for small producers.[23]
- **Alternative proteins:** Research investments with a long-term goal of making alternative proteins a reliable and affordable option are needed in high- and middle-income countries (HMICs), to replace high levels of animal-source food intake, and in LMIC contexts with high levels of malnutrition, to reduce child malnutrition with high-quality protein sources.[24]
- **Digital services:** Increased RD&D to advance uptake of digital agriculture and climate services should focus on: 1) the design of contextually appropriate digital agriculture and climate services; 2) identification of successful strategies for scaling up services and reaching poor smallholder farmers; and 3) assessment of the impacts of scaling up digital agriculture and climate services.[25]
- **Crop breeding:** Strengthen existing international initiatives for crop breeding to complement the development of new crop varieties, with a focus on new RD&D needs

[23] See section 6.6 in the CGIAR report.
[24] See section 3.6 in the CGIAR report.
[25] See section 8.6 in the CGIAR report.

such as development of these varieties through participatory protocols that engage a community or group of farmers in crop breeding for climate resilience. Organisations such as the CGIAR, FAO, International Union for the Protection of New Varieties of Plants (UPOV) and the Codex Alimentarius Commission set up by the World Health Organization (WHO) and FAO[26] can play an important role in this regard. These processes are needed to ensure that the benefits of accelerated genetic innovations and increased deployment of new technologies are shared equitably with smallholder farmers and the broader scientific community.

When aiming to promote the uptake of innovations believed to be technologically ready, governments should undertake a robust economic and financial analysis (EFA) for their specific context and application. Development partners such as the FAO or World Bank should host a database of these context-specific EFA variables and outcomes and organise them by region, country and agroclimatic conditions, among other things. Governments should systematically share their EFA data with such an international database to allow faster and better-informed uptake of ready technologies in areas, regions or countries with similar conditions.

> RECOMMENDATION A4 HAS BEEN UPDATED AS FOLLOWS:
>
> Governments, research organisations and companies should work together to deliver higher levels of investment in agricultural research, development and demonstration, to be maintained over the course of this decade. Priority should be given to innovations that can reduce methane emissions from livestock, make alternative proteins a reliable and affordable option, increase the resilience of crops, and advance uptake of digital services by farmers.

INTERNATIONAL EFFORTS SHOULD WORK TOWARDS ENABLING THE PRIVATE SECTOR TO SCALE UP SOLUTIONS THROUGH GLOBAL MARKETS

OVERVIEW

In last year's report we recommended that governments should begin a strategic dialogue on how to ensure international trade facilitates, and does not obstruct, the transition to sustainable agriculture. International organisations can advise on options to ensure a level

[26] See section 5.6 in the CGIAR report.

playing field so that policy measures essential to drive the transition do not put a country's agricultural sector at a competitive disadvantage in international trade. Early priority should be given to agreeing sustainability standards for the agricultural commodities that contribute disproportionately to deforestation.

WHAT PROGRESS HAS BEEN MADE?

We assess that minimal progress has been made against the recommendation we made last year.

In 2023, the World Trade Organization (WTO) participated in the Agricultural Ministers' Conference at the 15th Global Forum for Food and Agriculture in Berlin, suggesting that the role of trade in the transition to sustainable agriculture is beginning to appear on the international agenda. We have not, however, comprehensively tracked progress against this recommendation and other positive initiatives may well be underway. There remains a need for countries to begin substantial, sustained discussions to ensure that international trade supports the transition to sustainable agriculture.

WHAT MORE NEEDS TO BE DONE?

The private sector investment that is needed for the transition requires the right enabling environment, with clarity and consistency on the "rules of the game". More than the level of tax or the cost of labour, firms rank the legal and regulatory environment high among the factors affecting their investment decisions. Given high levels of international trade in both agricultural inputs and agricultural produce, in many cases international agreements on standards and trade will be critical to creating the necessary regulatory environment and investor confidence. Further, robust consumer demand for internationally traded goods is the enduring incentive for private investment and the exit strategy for public subsides. The universal availability of information about more sustainable technologies and on their benefits and risks to consumers influences consumer demand, and the international community has much to contribute to resolving current information asymmetries.

In last year's report we highlighted the agricultural commodities that contribute disproportionately to deforestation as a subsector to be prioritised. Here we propose priorities relevant to the seven technology solution areas discussed in this chapter. We suggest the following priorities:

- **Alternative proteins:** Countries should work together through forums such as the Codex Alimentarius Commission informed by expert organisations such as the FAO, Good Food Institute (GFI), WRI and the CGIAR[27] to develop common standards, regulations, metrics, labelling norms, and methodologies for assessments of environmental, social, health and nutrition impacts and for ensuring overall food safety

[27] See section 3.6 in the CGIAR report.

of newer alternative proteins. Such standards will be important for consumer confidence and for informed choice around more climate-friendly proteins, particularly in HICs where current meat consumption is higher than global averages. The harmonisation of regulations internationally would facilitate trade in alternative proteins and reduce risks to the private sector.

- **Low-emission fertilisers:** Countries should work to agree harmonised standards and regulations to level the playing field with high-emission alternatives on regulatory costs. Countries could hold talks on this issue and use forums such as the Policy Dialogue on Transition to Sustainable Agriculture or the Global Research Alliance on Agricultural Greenhouse Gases (GRA) to discuss experience and regulatory proposals. Advice could be sought from expert bodies such as the International Nitrogen Management System and the International Nitrogen Initiative.[28]
- **Crop and livestock breeding** is critical to both adaptation and mitigation. Countries should work together to develop and implement Intellectual Property frameworks that clearly set out the rights and responsibilities of the private and public sectors and those of international breeding bodies and their local community partners. This is needed to ensure that poorer farmers have access to resilient and low-emission crop and livestock varieties. Expert partners that could support countries in such an endeavour could include, among others, CGIAR, FAO, UPOV and the Codex Alimentarius Commission.
- **Agroecology:** Countries should work towards the harmonisation of standards and terminology for the products of agroecological and other sustainable agricultural approaches. Clearer labelling and certification enables incentives in the form of premiums, raising the profitability of producing these goods, and resolving any confusion that could lead to cynicism among investors and consumers, constraining demand.[29] Without harmonisation on definitions and labelling, it may be more difficult to spread these approaches rapidly through global markets.

Across all breakthrough technologies for which the private sector is a key scaling actor, international dissemination of successful business models and experience with risk-sharing financial instruments can be effective in attracting greater private sector investment. International measures such as these provide a predictable operating environment for the private sector which reduces risk and can boost investment in technologies that will impact the different dimensions of agricultural breakthrough. They also support high quality evidence to inform consumer demand, further supporting market-driven alignment with climate goals.

[28] See section 2.6 in the CGIAR Report.
[29] See section 7.6 in the CGIAR report.

RECOMMENDATION A5 HAS BEEN UPDATED AS FOLLOWS:

Governments should begin strategic dialogues on how to ensure international trade facilitates, and does not obstruct, the transition to sustainable agriculture. In addition to addressing the agricultural commodities that contribute disproportionately to deforestation, early priority should be given to agreeing standards, labels and regulations for alternative proteins, low-emission fertilisers, and products of agroecological and other sustainable approaches, and to developing intellectual property frameworks that promote access to resilient and low-emission crop and livestock varieties. This should be complemented with international sharing of best practice on mobilising private investment and engaging consumers.

ISSUES NOT COVERED IN THIS CHAPTER

In this chapter we have focused on opportunities for international collaboration to accelerate the adoption of solutions in seven technology areas. While these are important priority areas, they are not comprehensive. Other technology and solution areas will also be important to the just transition to sustainable agriculture. These include emissions reduction from rice paddies, improved water management as a climate adaptation strategy with mitigation co-benefits, and the promotion of more healthy and sustainable diets. Wider concerns, including antimicrobial resistance and zoonotic diseases, and broader issues of inclusion and social justice, will also be relevant to the transition in the sector. We encourage governments and international organisations to continue to develop a stronger shared understanding of the opportunities and risks around the transition to sustainable agriculture, and of the priorities for international collaboration.

CHAPTER 9. CROSS CUTTING

LEVERAGING CROSS-CUTTING OPPORTUNITIES

There are a number of cross-cutting opportunities, which are common across the current and potential Breakthrough Agenda sectors. International action in these areas can help to support progress in all sectors simultaneously.

ESTABLISH A CLEAR STRUCTURE FOR INTERNATIONAL COLLABORATION WITHIN EACH SECTOR

Over the past year, the respective Breakthrough processes have become increasingly established in their sectors, enabling countries to strengthen their shared understanding of the collaborative initiatives already underway, and of the priorities for international collaboration going forward. As this report demonstrates, the effectiveness of these efforts has varied between sectoral Breakthroughs and action areas, but overall the structure provided by the Breakthrough Agenda has helped to improve collaboration in each sector.

Active participation by the countries with greatest influence over global markets in each sector is vital for collaboration to be effective. Insufficient participation can result in weak impacts or divergent approaches, which risk putting a brake on the transition. For example, China, the United States, the European Union, India and Japan together represent over 75% of the market in road transport and also in steel, yet there is currently no sector-specific forum in either of these sectors where they all collectively collaborate on issues relating to the transition.

The nature of participation is also important. The participation of government officials responsible for domestic policy in the relevant sectors can enable a higher quality of dialogue than participation only of officials responsible for foreign affairs. The involvement of ministers and senior officials can be important to giving collaborative initiatives the political mandates they need to succeed, and to reaching decisions on major issues. Participation of private sector and civil society representatives can also enhance the quality of collaboration by providing relevant knowledge and perspectives.

The greatest success for sectoral collaboration can be observed where key forums have been adequately resourced and proactive in bringing together relevant participants on a regular basis. The provision of detailed analysis and evidence can support high-quality dialogue between countries, and the provision of financial and technical support to countries can be a valuable complement to political dialogue. This has worked well under the Hydrogen Breakthrough, for example, where governments provided funding for a World Bank study on the role of financing in supporting the development of a hydrogen supply chain in developing countries after this being identified as a useful next step during the breakthrough dialogues.

Efforts to improve the co-ordination of international action have been most successful in sectors where the landscape of relevant initiatives is relatively young and still growing (such as for hydrogen and steel), in which collaboration has been facilitated by flexible workplans that can be more readily shaped and co-ordinated by collaborative efforts. In sectors that are more advanced in their transition (such as power), where there are many more long-standing collaborative forums, it has been more difficult for countries to achieve a clear and common view of the collaboration that is already happening and to identify where further collective efforts could be most impactful.

In terms of the core tasks that make international collaboration simpler and easier, stakeholders have often referenced the mapping of initiative landscapes as being very helpful. To date, there has only been a single static publication of these maps (in last year's report), limiting their usefulness. To maximise the benefit of this exercise, we suggest that these maps should be regularly updated by the Breakthrough Agenda secretariat, be readily available (e.g. on a website) and provide additional detail on workplans and contacts.

In summary, a significant amount of learning can be drawn from the time since the Breakthrough Agenda was launched at COP 26 and what it can tell us about more or less successful models and tools for strengthened international co-operation. Replicating and applying some of the best practice, as covered in this section, can ensure stronger collaboration that can deliver better outcomes for all.

RECOMMENDATION CC1 HAS BEEN UPDATED AS FOLLOWS:

Countries should further strengthen forums and institutions that support international co-operation in each sector, with increased political and financial support, sufficient participation, and deeper analysis and communication of the potential gains from co-ordinated international action.

STRENGTHEN THE PROVISION OF TECHNICAL ASSISTANCE AND FINANCE, TO ENSURE IT IS SUFFICIENT, COHERENT, ACCESSIBLE AND EFFECTIVE ACROSS ALL SECTORS

Last year's report noted the importance of improved co-ordination of the financial and technical assistance offer in each sector. Strengthening the provision of finance should include: 1) ensuring sufficient assistance is available (this varies significantly between sectors); 2) better co-ordination of assistance to simplify the offer and improve access; and 3) improving the flexibility of assistance, tying it more closely to political dialogue between countries. The chapters on each sector provide more specific recommendations on how

assistance offers could be designed, scaled-up or better integrated within the current landscape.

In terms of better co-ordinating assistance, there has been success in the development of sectoral matchmaking platforms. These are platforms that bring together donor and recipient countries, along with international financial institutions, philanthropic organisations, technical partners and the private sector, to better identify appropriate routes to technical and financial assistance based on recipient country requests.

The power sector is most advanced, with platforms such as the Energy Transition Council. The transport sector has developed a lighter touch offering, with the Zero Emission Vehicles Transition Council International Assistance Taskforce, whereas other sectors, such as steel, cement and buildings, could benefit from similar platforms being developed. This could include scaling up existing platforms, or building something new, depending on the sector. These sectors should learn from the experience in the power and transport sectors and clearly set out the boundaries and areas of co-ordination or overlap between them (for example, where hydrogen activities overlap with steel). As sectoral matchmaking platforms develop, they would benefit from the establishment of a light-touch network to share best practice and clarify areas of activity. These should also work closely with the existing joint multilateral development bank (MDB) collaboration, which also includes several sectoral inter-MDB groups.

Beyond improved co-ordination, over the course of 2022 there has been growing momentum behind proposals to improve international climate finance and also to reform the global financial architecture more broadly. Recipient countries have raised several issues with the current mode of delivery of international climate finance and practical assistance, citing long lead times and overly bureaucratic applications for projects, as well as a lack of financing for major, deep decarbonisation projects, unfavourable loan conditions, and insufficient support for short-term disasters caused or influenced by climate change.

The Bridgetown Initiative, launched in September 2022 by Barbados, is spearheading efforts to make the global financial architecture more conducive to action on climate change. As part of this initiative, supporters are requesting that banks improve loan conditions to avoid developing countries spiralling into debt, provide an additional USD 1 trillion from development banks and establish a new mechanism – with private sector backing – to fund climate change mitigation and reconstruction after a climate disaster. Partly in response, France organised the "Summit for a New Global Financing Pact" in June 2023, with the aims of restoring fiscal space to countries facing short-term difficulties, fostering private sector development, encouraging investment in "green infrastructure" and mobilising innovative financing. While it is still too early to assess the success of the outcomes of this Summit, the proposed next steps look promising, with a roadmap setting out opportunities for counties to build momentum towards agreement on the aforementioned issues at the G20 and UN General Assembly.

Faced with a changing context and increasing calls for improvement from recipient countries, MDBs are also reassessing their role. The World Bank published Evolving the

World Bank Group's Mission, Operations, and Resources: A Roadmap in January 2023, framing the key questions that the Bank aims to tackle as it considers priorities for reform. This includes aligning all new operations with the Paris Agreement by 1 July 2023, with the International Finance Corporation and Multilateral Investment Guarantee Agency aligning 85% of their sectoral operations in the same period, rising to 100% by 1 July 2025. The Action Plan also includes a new climate finance target that would rise to an average of 35% of total World Bank funds between 2021 and 2025, with at least 50% of International Bank for Reconstruction and Development (IBRD)/International Development Association (IDA) funds being used for adaptation over the same period.

The World Bank has also begun producing Country Climate and Development Reports (CCDRs) with partner countries, which set out the main pathways to reduce GHG emissions and climate vulnerabilities. There are now CCDRs for 25 countries, which will be shared across MDBs to better co-ordinate activities, although the extent of their application varies between countries, depending on the level of cross-government buy-in to the reports.

Several major donor countries have significant influence over the future of the climate finance on offer, with Japan, Germany, France, the European Union (institutions), the United Kingdom, the Netherlands, the United States, Australia, Norway and Italy representing the top ten countries for climate-related overseas development aid (in order of contribution). Such countries could increase the impact of their climate finance if they also ensure that the global financial architecture is appropriately reformed to better enable private investment in the transition in developing countries, informed by the proposals put forward under the Bridgetown Initiative.

To increase finance for climate action from public and private sources, a series of Regional Finance Forums were organised in 2023 through the collaborative action of the five UN Regional Commissions, the COP 28 and COP 27 Presidencies, the UNFCCC and the UN Climate Change High-Level Champions, building on the successful outcomes of the first edition of the forums held in 2022. These aim to provide a platform for public and private investors to connect with developers of projects on climate mitigation, adaptation and resilience, in order to bridge the gap in investment for critical, climate-related projects. As a result of the 2022 edition, more than 400 projects from over 30 countries were identified and listed in the Compendium of Climate Related Initiatives: Opportunities for Climate Finance and Investments on the SDGs, with project ticket size varying from USD 1 million to USD 100 million. In 2023, similar forums have been held in the Asia-Pacific region and in Europe, and two Africa matchmaking sessions were held to support fundraising via for 65 projects.

In summary, there have been significant improvements in the co-ordination of financial and technical assistance within major emitting sectors, with useful learning from successful delivery models. Further efforts will be required to reduce lead times for projects, improve loan conditions (particularly for at-risk recipient countries), prioritise structural emission reductions (vs. incremental improvements) and provide adequate support for disaster response and adaptation.

RECOMMENDATION CC2 HAS BEEN UPDATED AS FOLLOWS:

Governments, financial institutions, philanthropic organisations and delivery partners should continue to improve the co-ordination of technical and financial assistance in each sector, learning from existing successful models. Further efforts are required to improve the conditions and delivery of financial assistance, in line with developing country requests.

AGREE NET ZERO-ALIGNED TRADING ARRANGEMENTS THAT CAN ENABLE A FASTER TRANSITION ACROSS SECTORS AND REGIONS

Last year, we recommended that governments, companies and relevant international organisations should establish high-level, strategic dialogues in those sectors where an unlevel playing field is at risk of presenting a major barrier to the transition. Since then, there has been an increase in efforts to facilitate such dialogues, albeit at a very early stage and among a limited set of countries.

One important effort to initiate such dialogues was the establishment of the Climate Club, whose Terms of Reference (ToR) were agreed by the G7 in December 2022. The Climate Club aims to accelerate the decarbonisation of industry sectors, through comparative work on mitigation approaches between members, sharing experience and potentially co-ordinating industry decarbonisation approaches, and improving financial and technical assistance.

A total of 27 governments have joined the Climate Club, but only 2 of the top 10 emerging and developing countries by GDP. Germany and Chile are leading a Task Force of senior officials to further develop a work programme for the Club, which has the potential to include strategic dialogues on “carbon leakage and other risks to mitigation efforts”, as set out in the ToR. Whilst it is still too early to assess the effectiveness of the Climate Club, its “open and inclusive” approach has the potential to create an important forum to discuss these issues, with no major limits or requirements currently placed on membership. Its success will be strongly contingent on the inclusion of major industrialising countries, including China, India and Brazil.

The World Trade Organization (WTO) will also be vital for supporting government dialogue on trade, as governments move to decarbonise. Increasingly, the WTO is engaging on this as a central issue, including expanding the work of its Trade and Environmental Sustainability Structure Discussions, holding important information events for members during its Trade and Environment Week and using its powerful convening role to bring together varied stakeholders on more sector-specific topics (see Trade Forum on steel standards). In particular, it is worth noting the inclusion of representatives of major producer and consumer economies in the WTO’s discussions, including those of the United States, China, India and the European Union, where other forums may struggle to draw together

high-level input from all these countries. Further movement towards sector-specific talks could help build an understanding of the measures needed to remove barriers to the transition.

> RECOMMENDATION CC3 HAS BEEN RESTATED AS FOLLOWS:
>
> Governments, companies and relevant international organisations should establish high-level, strategic dialogues in each sector that is highly exposed internationally and where uneven competition risks being a barrier to the transition, to develop a common approach to reaching a level playing field. This should include, where relevant, actions on data, standards, procurement, technology collaboration and technical and financial assistance, as well as trade.

URGENTLY SCALE UP DEMONSTRATION PROJECTS FOR CLEAN TECHNOLOGIES IN AREAS OF GREATEST NEED

As set out last year, the world needs to rapidly increase the number of demonstration projects of clean energy technologies and sustainable agriculture solutions across multiple regions and sectors in parallel. International collaboration will be important in determining the priority gaps to address, and in ensuring continuous, deep, systematic and widespread sharing of learning between countries. During 2022 we saw important developments in several key technologies, including sodium-ion batteries (technology readiness level[1] [TRL] 4 -> 6) and direct reduced iron using electrolytic hydrogen (TRL 5 -> 6).

In September 2022, 16 governments[2], including the European Union, came together to commit USD 94 billion for clean energy demonstration projects. This level of funding was in line with an IEA assessment of what would be needed to complete a portfolio of large-scale demonstration projects this decade in order to bring to market the technologies required to achieve net zero emissions by 2050. In the countries behind the commitment, new institutional structures have been put in place to track development, such as the Office of Clean Energy Demonstrations in the US Department of Energy.

In this year's report, we note several successful examples of private sector collaboration, in particular the Innovandi research network in the cement sector, as well as examples of company partnerships on novel technologies in the steel sector. This form of collaboration

[1] Technology readiness level (TRL) refers to the current stage of maturity for a given technology solution, ranging from an initial idea or concept to commercial-scale operation.
[2] Australia, Canada, European Union, Finland, France, Germany, Japan, Korea, the Netherlands, Norway, Poland, Singapore, Sweden, the United Arab Emirates, the United Kingdom and the United States.

is not yet as well developed in all sectors, with a particular focus required to strengthen public-private collaboration in all sectors, through forums such as Mission Innovation (MI).

Over the past year, MI has continued to support the development of seven major Missions, covering power, hydrogen, industries, shipping, CO_2 removal, biorefineries and the built environment. In September 2022, the 23 governments and the European Union which collaborate through MI set out National Innovation Pathways and launched Mission Innovation Mission Action Plans to deliver 221 demonstration projects globally this decade, accelerating clean energy technologies in the sectors in which emissions are hardest to abate. MI aims to drive public-private investment in technologies which need to be commercialised by 2030, including at least 50 large-scale demonstration projects to decarbonise energy-intensive industries like steel, cement and chemicals; 5 projects on 5 continents to demonstrate the integration of up to 80% renewable energy into energy grids; and the identification of 100 'hydrogen valleys' worldwide.

It will be important for countries to put in place structures and processes for rapid and deep sharing of learning from these demonstration projects, for the full potential of faster innovation arising from these internationally aligned efforts to be realised.

> RECOMMENDATION CC4 HAS BEEN RESTATED AS FOLLOWS:
>
> Governments and companies should greatly increase spending on clean technology demonstration projects, working together to bring new technologies to commercial-scale deployment as soon as possible. Early deployment projects should be supported by matchmaking forums and ensuing commitments and processes in all regions.

ACCELERATE THE BUILD-OUT OF INTERNATIONAL ENABLING INFRASTRUCTURE TO SUPPORT THE TRANSITION IN MULTIPLE SECTORS

Last year, we recommended that governments in each region of the world should agree to the top priority common infrastructure projects that can support near-term growth in the deployment of clean solutions. Since then, there has been some promising progress, particularly in the power sector, with regards to the development of regional cross-border electricity trade via interconnectors (see the Power chapter). In other sectors, where more novel infrastructure is required (for example, hydrogen and CO_2 transport and storage), progress has been limited, restricted by uncertain policy and weak regulatory support, other than in the most advanced economies.

Countries should continue to work towards harmonising standards for electric vehicle charging or refuelling, helping to lower the costs of infrastructure-related equipment such as fast chargers and storage solutions for hydrogen for refuelling stations.

Co-ordinated investment in zero-emission refuelling infrastructure will be essential for the decarbonisation of long-distance aviation and shipping. This includes low-emission international corridors for maritime freight and aviation, which will require co-ordination regarding the development of refuelling infrastructure at ports that is compatible with agreed low-emission fuels definitions for these sectors. In the case of hydrogen, these ports could also serve as hubs to facilitate the adoption of low-emission hydrogen in other sectors, requiring close collaboration with different end users.

Beyond building new infrastructure, there are also opportunities for countries to learn from one another when repurposing existing fossil fuel infrastructure. This includes repurposing oil and gas infrastructure to transport hydrogen and captured CO_2, as is being explored by the United Kingdom's North Sea Transition Authority. In the United States, the Department of Energy is investigating building new nuclear reactors at coal-fired power plant sites, reusing the existing coal and electricity infrastructure (e.g. transmission lines, cooling ponds or towers and civil infrastructure).

One of the main challenges for any large-scale infrastructure projects is the long lead times. For key clean energy technologies, this can range from less than a year to up to four years for utility scale solar PV, or from two years to seven years for offshore wind. Sharing best practices among countries on improving the planning and permitting processes, so that all countries can move towards the lower end of these ranges, will be vital to get sectors on track for net zero emissions by 2050.

> RECOMMENDATION CC5 HAS BEEN RESTATED AS FOLLOWS:
>
> Wherever not already agreed, governments in each region of the world should agree to the top priority common infrastructure projects that can support near-term growth in the deployment of clean solutions, such as interconnectors and hydrogen pipelines. In each of the land, sea and air transport sectors, countries and companies should identify specific international routes to be prioritised for the co-ordinated first deployment of zero-emission charging or refuelling infrastructure.

PROVIDE CLEAR GUIDANCE AND VERIFICATION OF EMISSION REDUCTION STANDARDS COMPATIBILITY WITH NET ZERO TO FACILITATE GREATER USE

As covered in all sectoral chapters, standards will be an increasingly useful tool to set a common expectation for the rate of decarbonisation in each major emitting sector. They

will also be vital for potential customers, governments and those tracking progress for a range of policy measures and contracts. These include procurement contracts, trade deals and access to finance, as we are starting to see across the hydrogen, steel and cement sectors.

A common risk is the complexity of verification across the different standards being proposed, i.e. how does a company or government understand whether a product is meeting its intended standard, and how do they know if this standard is aligned with a trajectory to net zero emissions or to curbing warming under 1.5 °C. Whilst we are at a relatively early stage of 'net zero-aligned' standards development in most sectors, there are already a range of alternative and conflicting standards being proposed by companies, standards bodies and governments, which can cause confusion for potential users.

In some cases, this can be mitigated using similar principles or codes for the development of sustainable standards. At a cross-sectoral level, the International Social and Environmental Accreditation and Labelling Alliance (ISEAL) is one example of an organisation providing Codes of Good Practice to help guide organisations in the robust development of sustainable standards. Whilst useful for general guidance, it does not provide the level of product specificity required in many of the major emitting sectors.

Within several sectors, there is ongoing work to develop or build on principles for standards. This includes the work started by the G7 for steel and hydrogen, as well as the work of the International Organization for Standardization (ISO). Work on principles for standards is different to the development of standards themselves. The ISO tends to focus on the use of standards for emissions measurement – such as emissions accounting methodologies. However, there are unanswered questions about normative emissions thresholds, or a 'quality' standard.

As a result, these existing efforts do not yet go so far as to provide potential customers or policy officials with definitive guidance on which standards are sufficiently ambitious. This would require an assessment of the extent to which standards are compatible with internationally agreed climate goals. Such an assessment would need to include a technical assessment (i.e. what emissions would result from the application of such a standard) and a scenario assessment (what emission level would be compatible with climate goals).

At the level of individual entities rather than that of economic sectors, an example of such an assessment function is the UN High-Level Expert Group on the Net Zero Commitments of Non-State Entities, which attempts to mitigate the potential risk of greenwashing, particularly from company-level net zero claims. The Group's report, published at COP 27, sets out ten recommendations for setting credible net zero targets for non-state actors. This was championed by the UN Secretary General as a way to set a "zero tolerance" approach to greenwashing. Such a function does not itself assess the compliance with net zero targets with international climate goals, but rather assesses the way these goals are defined. This can provide guidance to the many companies that have committed to net zero targets as part of the Race to Zero campaign.

In alignment with the UN High-Level Expert Group, ISO launched its own guidelines at COP 27 last year, which go some way towards providing this guidance. The guidelines provide recommendations to enable a common approach with a high level of ambition, to drive organisations to achieve net zero as soon as possible, and by 2050 at the latest. They are intended as a common reference for governance of organisations (including voluntary initiatives, adoption of standards, policy and national and international regulation), and can help organisations taking action to contribute to achieving global net zero. These represent a major and positive step forward in improving guidance around net zero standards, although stop short of providing the function to conduct that assessment themselves. Such a function would require credible international experts, with detailed knowledge of each sector.

In summary, there would be a clear co-ordination benefit to countries clarifying and agreeing on the standards in each sector that are sufficiently ambitious to align with international climate goals. This could reduce complexity and confusion, and increase the rate of adoption of the most appropriate standards. Through delivering co-ordination on standards at a cross-sectoral level, as well as within sectors, experts can ensure that different fuels, materials and products are being treated with equivalent approaches. This is particularly important in cases where products can provide substitutes for one another, such as steel and cement in construction.

RECOMMENDATION CC6:

Building on existing international efforts, governments should consider the establishment of an international function to improve the collective verification of claims of different standards and their compatibility with international climate goals, across multiple sectors.

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