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ASSESSMENT OF THE G20 MEMBERS' LONG-TERM STRATEGIES

Commonalities, gaps and areas for cooperation

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SUMMARY

Under Article 4 paragraph 19 of the Paris Agreement, countries are encouraged to formulate and communicate long-term low greenhouse gas emission development strategies (LTS). LTS set out long-term visions that can inform climate action and investments on the short to medium term. Collectively, LTS should chart the pathway to achieving global net zero CO_2 emissions by 2050. They can be a useful planning component to inform NDCs, sectoral mitigation and adaptation plans, and investment plans.

Seventeen G20 members had submitted an LTS, outlining their long-term decarbonisation and development plans, by July 2023. This report systematically assesses these 17 LTS to identify commonalities, opportunities for international cooperation, and gaps that can be addressed in future LTS submissions. We chose to analyse G20 members as they represent over 80% of both the global GDP and greenhouse emissions, in addition they have a significant impact on global decisions that impact long-term global decarbonisation efforts.

KEY ENABLERS: TECHNOLOGY, FINANCE, AND CAPACITY BUILDING

Fifteen out of 17 LTS we analysed acknowledge the need for R&D in key technologies crucial for their long-term transformations, and many explicitly identify it as a priority and international cooperation area. International R&D partnerships should encourage increased participation from Global South countries to better inform innovation priorities and to facilitate equitable access to latest technologies.

While most G20 members acknowledge the role of climate finance, only six of the 17 we analysed include quantitative estimates in their LTS. We also identify a further lack of details on how adequate climate finance will be mobilised for their long-term transformations. Only five G20 members refer to their existing commitments or mention their intention to provide international climate finance.

Finally, whereas 11 of the 17 G20 members recognise the need for capacity building to achieve long-term transformation, they say little about their exact capacity needs or the potential for international cooperation in this area.

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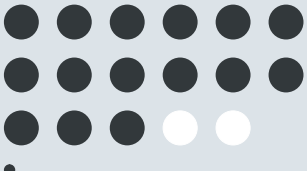

acknowledge the need for R&D to facilitate their long-term transformations

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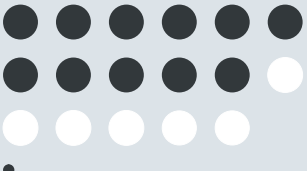

acknowledge the need for capacity building to meet their long-term targets

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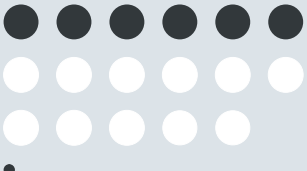

provide estimates for the amount of finance and investments needed to meet their long-term targets

ADAPTATION AND LOSS & DAMAGE

Few G20 members' LTS contain adaptation targets and measures. Only eight of the 17 LTS mention the need for adaptation finance but fail to quantify these needs. Several countries acknowledge the role of international cooperation in both adaptation and adaptation finance. India and Indonesia are the only two G20 members to refer to loss and damage in their LTS.

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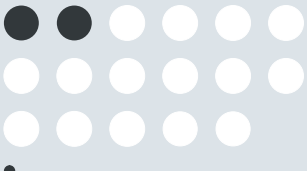

mention loss and damage

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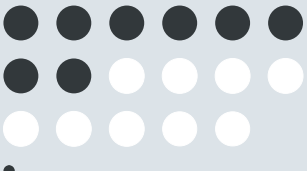
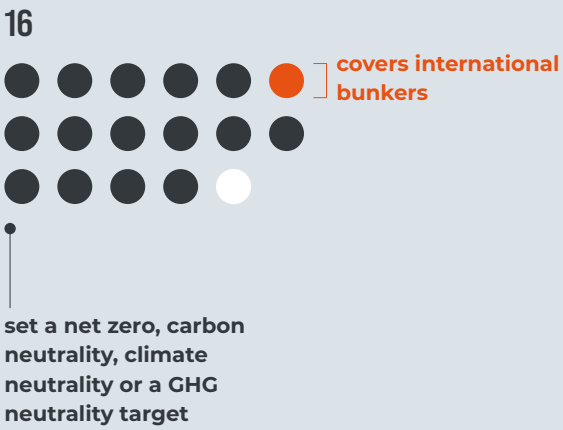


discuss adaptation finance

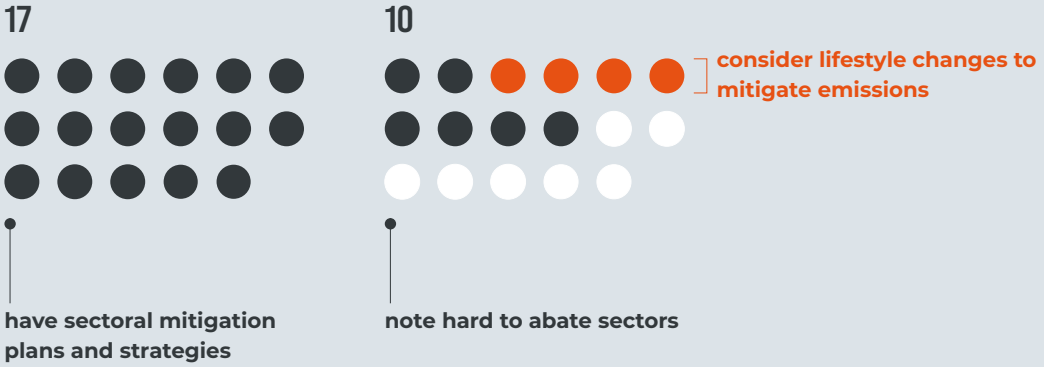
HEADLINE TARGETS

Sixteen of the 17 LTS present a net zero target. Twelve of them target net zero by 2050, whereas Germany aims for 2045, China and Indonesia 2060 and India 2070. The pace of the transition will be faster for Global South than for Global North countries, considering the difference between their peak emission years and headline target years, and the former will thus require proactive technical and financial support from the latter to achieve their long-term transformations. The UK is the only G20 member to cover emissions from international aviation and shipping in its net zero target.



SECTORAL TARGETS

All G20 countries we analysed have sectoral decarbonisation targets or plans in their LTS. Most countries prioritise such plans for the power, buildings, agriculture, industry, and transport sectors, and fewer countries prioritise the waste sector. Only four G20 members outline lifestyle-related mitigation plans, mainly focusing on demand-side management, energy-efficient behavioural nudges, and educational programmes. However, no country mentions lifestyle change as a key measure for reducing demand for and emissions from agriculture and international aviation.



ENERGY

All 17 LTS mention energy efficiency. While 16 G20 members refer to renewable energy as a key part of their decarbonisation strategies, only a few provide specific targets. Most G20 members also consider hydrogen a key decarbonisation opportunity, with applications in industry, transport, refining, and power sectors. All countries plan to use bioenergy as part of their decarbonisation efforts, and nine also mention BECCS as an emissions removal technology to achieve net zero targets. Renewables, hydrogen, nuclear, and bioenergy all have sustainability impacts, which are not acknowledged in most LTS that anticipate a role for these technologies.

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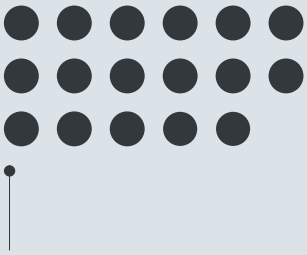
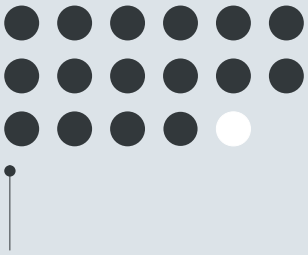


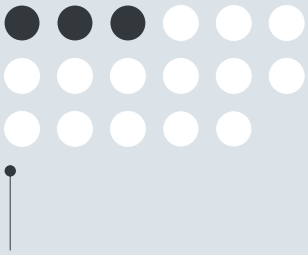
mention some form of energy efficiency or the other

16



note the use of renewable energy for decarbonisation

3



want to be hydrogen exporters

FOSSIL FUEL PHASE OUT

While several G20 members mention plans to reduce their dependence on fossil fuels gradually, France is the only G20 member to commit to phasing out fossil gas and oil exploration on its own territory in its LTS. Although we identified statements on the phase-out of fossil fuel subsidies in nine of the 17 LTS we analysed, they lack clarity regarding the fuels covered and the phase-out timeline.

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to completely phase-out fossil gas or oil exploration on its own territory

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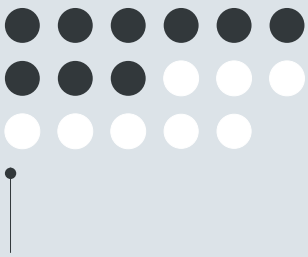
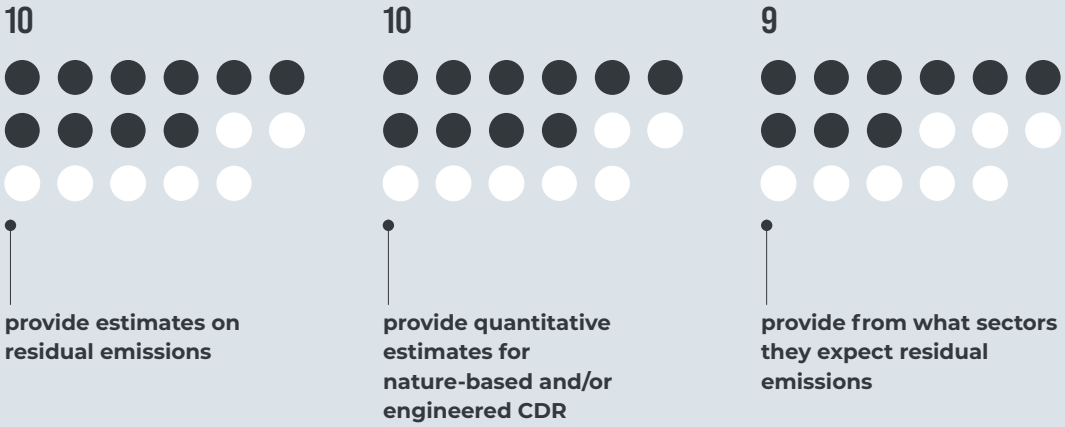


refer to phasing out fossil fuel subsidies

RESIDUAL EMISSIONS

The G20 countries we assessed aim to reduce on average 72-81% of their 2019 emissions by 2050. To achieve net zero, these residual emissions must be offset with CDR, either through nature-based or engineered methods. The ten countries providing estimates on residual emissions expect joint emissions of 3-4.3 $GtCO_2e$ in 2050, which implies the need for substantial carbon removal efforts. Ten of the LTS provide quantitative estimates for CDR, with nine LTS providing estimates for nature-based CDR and six for engineered CDR. Nine of the G20 members assessed see a role for BECCS but do not address how to account for emissions from bioenergy production, transport, and use across national borders.



RECOMMENDATIONS

Our assessment results in a set of recommendations for G20 members, formulated along four broad action points: Include, Specify, Enhance, and Cooperate on.

INCLUDE

We recommend the G20 members to include the following in future LTS submissions:

- International climate finance commitments
- An investment plan to achieve long-term targets
- Adaptation targets and measures
- Acknowledgement of loss and damage
- Mitigation targets and plans for all economic sectors
- Targets and plans for energy efficiency
- Behavioural measures and the role of sustainable consumption
- Transparent assumptions on nature-based and engineered CDR

SPECIFY

We recommend the G20 members to be more specific on the following topics that are only vaguely addressed in current LTS:

- Finance needs for mitigation and adaptation
- Capacity building needs
- Use of international offset credits in net zero targets
- Type of hydrogen to be used for decarbonisation
- Scope and coverage of fossil fuel phase out commitments (including fossil fuel subsidies)
- Residual emissions levels in the net zero target year

ENHANCE

We recommend the G20 members to enhance their climate ambition by:

- Committing to earlier target years for net zero emissions
- Committing to deep emissions reduction targets alongside their net zero targets
- Considering and addressing the potential negative sustainability and climate impacts of bioenergy and BECCS
- Improving the accounting methods and guidelines for BECCS

COOPERATE ON

We recommend the G20 members to cooperate internationally on the following topics:

- Inclusive R&D partnerships
- Knowledge sharing on behavioural measures and sustainable consumption
- Capacity building programmes
- Critical minerals supply chains
- Hydrogen taxonomy development
- Phase out of fossil fuel subsidies
- Co-development of robust accounting methodologies for land use and BECCS

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ABBREVIATIONS

A/R	Afforestation and Reforestation
BECCS	Bioenergy with Carbon Capture and Storage
CBDR-RC	Common but Differentiated Responsibilities and Respective Capabilities
CCS	Carbon capture and Storage
CDR	Carbon Dioxide Removal
COP	Conference of Parties
CO_2	Carbon dioxide
CSP	Concentrated Solar Power
DACCS	Direct Air Carbon Capture and Storage
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gas
$GtCO_2e$	Gigatonnes of carbon dioxide equivalent
GW	Gigawatt
IPCC	Intergovernmental Panel on Climate Change
NDC	Nationally Determined Contributions
LTS	Long-Term Strategy (or Strategies)
LULUCF	Land Use, Land-Use Change and Forestry
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaics
R&D	Research and development
tCO_2	tonnes of carbon dioxide
UNFCCC	United Nations Framework Convention on Climate Change
UK	United Kingdom
USA	United States of America
USD	United States Dollar
ZEVs	Zero-emission Vehicles

01 CONTEXT AND OBJECTIVE

In the 2015 Paris Agreement, countries agreed to keep global temperature rise to well below 2°C above pre-industrial levels and to pursue efforts to keep the increase below 1.5°C (UNFCCC, 2015). The Paris Agreement requires all countries to set and regularly enhance ambitious climate targets, known as Nationally Determined Contributions (NDCs). However, NDC targets are only until 2030, while decarbonising economic systems need long-term pathways beyond 2030.

Article 4.19 of the Paris Agreement urges countries to "strive to formulate and communicate long-term low greenhouse gas emission development strategies, mindful of Article 2 taking into account their common but differentiated responsibilities and respective capabilities, in the light of different national circumstances". In the absence of a standard, internationally adopted guidance on the scope or format of long-term strategies (LTS), countries have adopted different approaches to set forth their priorities and highlight their national context while preparing the LTS. Most submissions note mitigation, adaptation, and means of target implementation, including, finance, technology, and capacity building. The inclusion of and level of emphasis on different topics in the LTS reflects the country's unique priorities and long-term vision.

This report aims to analyse commonalities and gaps in G20 members' LTS, and to identify areas of international cooperation and opportunities for improvement in future LTS development cycles. We chose to analyse G20 members as they cumulatively account for 85% of the global gross domestic product (GDP) and 80% of global greenhouse gas (GHG) emissions and have a significant impact on global decisions that influence long-term global decarbonisation efforts (Warren, 2021).

G20 members differ widely in terms of their population size, incomes, per capita emissions, and urbanisation levels. For instance, while China and India host over one billion people each, Australia has only 25 million inhabitants. Moreover, the G20 members' level of economic development is diverse – per capita GDP ranges from 2,399 United States Dollar (USD) in India to 76,398 USD in the USA, a staggering 32 times more (World Bank, 2023b, 2023c). Similarly, the G20 members' per capita emissions vary widely, as do their cumulative historical emissions. Per capita emissions range from less than 2 tonnes of carbon dioxide (tCO_2) per capita in Brazil and India to over 14 tCO_2 per capita in Australia and Saudi Arabia in 2020 (World Bank, 2023a).

These differences in national context influence countries' decarbonisation priorities and needs. For the purpose of this study, we group the G20 members in two categories: Global North and Global South. With Global North, we refer to countries that are members of the Organisation for Economic Co-operation and Development (OECD) or are listed in Annex I to the United Nations Framework

Convention on Climate Change (UNFCCC). The following twelve G20 members are part of the Global North: Australia, Canada, the European Union (EU), France, Germany, Italy, Japan, Russia, South Korea, Türkiye, the United States of America (USA), and the United Kingdom (UK). We refer to the remaining eight G20 members as Global South countries: Argentina, Brazil, China, India, Indonesia, Mexico, Saudi Arabia, and South Africa.

Conscious of the diversity of national circumstances among G20 members, this report does not intend to rate or compare their LTS. Rather, its goal is to better understand the visions and priorities articulated by G20 members through their LTS, and accordingly make recommendations for a variety of themes on international cooperation and future LTS enhancements. Our study builds on reports that outline best practices for LTS **(see → Literature review for an overview)** and literature assessing how certain topics are addressed in LTS, for example fossil fuel production and residual emissions (Buck et al., 2022; Jones et al., 2023).

02 METHODOLOGY

We utilised a three-step methodology to prepare this report:

A **Developing an assessment framework;**
B **Assessing individual country LTS documents; and**
C **Analysing cross-country data to extract findings.**

First, we reviewed literature on the role of LTS in achieving the Paris Agreement goals to identify what are generally considered best practices for LTS **(see → Literature Review)**. Based on these insights, we developed a comprehensive assessment framework to collect data from the G20 members' LTS. The assessment framework consisted of exactly 100 indicators across the following themes identified in the literature: adaptation and resilience, mitigation targets, energy and energy efficiency, fossil fuel phase out, carbon dioxide removal (CDR) and land use, land use change, and forestry (LULUCF), finance, trade, capacity building, technology transfer, and governance. In addition, we incorporated general questions on the G20 members' macroeconomic profile, economic and development goals, and considerations on equity and international cooperation to provide the context in which to interpret LTS commitments. See Annex 1 for an overview of all indicators.

Secondly, we collected data for each of the 17 G20 members that had submitted an official LTS to the UNFCCC (or the European Commission in the case of Italy) as of July 2023. Brazil, Saudi Arabia, and Türkiye had not submitted an official LTS at the time of this study. The scope of this study only included LTS submitted to the UNFCCC (and to the European Commission in the case of Italy). We excluded other related documents like NDCs or national-level climate strategy documents to maintain consistency. It should be noted that official LTS documents do not have a standardised format and the documents consulted vary widely in their lengths, level of detail, and coverage of topics **(see → Table 1)**.

The data collection stage involved manually going through each G20 member's LTS document and answering questions across the themes included in the assessment framework. Most questions had multiple choice answers to facilitate analysis and identification of trends, and we recorded additional or contextual information to validate each answer. Further, we systematically recorded instances where G20 members considered certain themes or questions to be a priority or a potential area for international cooperation. In general, we marked a theme to be priority or cooperation area when a G20 member (i) explicitly mentioned it as such, (ii) provided examples of policies or partnerships that can be interpreted as such, or (iii) dedicated a significant portion of the LTS document to that theme. It is important to note that the identification of priority and cooperation areas, despite being done systematically using the aforementioned principles, remains subjective due to the scope for interpretation.

Country	Year of submission	Languages available	Number of pages
Argentina	2022	Spanish	13
Australia	2021	English	130
Brazil	Not available		
Canada	2022	English, French	67
China	2021	Chinese, English*	45
European Union	2020	English	25
France	2021	English, French	176
Germany	2022	English	92
India	2022	English	121
Indonesia	2021	English	156
Italy	2021	Italian	100
Japan	2021	English	112
Mexico	2016	English	106
Russia	2022	Russian, English*	34
Saudi Arabia	Not available		
South Africa	2020	English	88
South Korea	2020	English	131
Türkiye	Not available		
United Kingdom	2021	English	368
United States	2021	English	65

* Unofficial translation

Note: (1) Year of submission refers to the latest version of the LTS. (2) For G20 members that submitted an LTS both in English and another UN language, we consulted only the English version and noted the page length of that version in this table. (3) For the LTS that were only available in a language other than English, we used online translation tools, with some interpretation support from native speakers.

Sources: (European Commission, 2021; UNFCCC, 2023).

Table 1

Overview of G20 LTS documents analysed for this study

After completing all country assessments, we conducted consistency checks for all questions and themes to ensure that similar information in different LTS was interpreted in the same way across countries. This was to ensure the robustness of our data.

Finally, once we completed the data collection and verification, we conducted cross-country analyses for each thematic area to extract and present findings. Through this exercise, we were able to identify commonalities, trends, and areas of cooperation to flag as windows of opportunity for the G20 process. We also noted gaps or deviations from best practices in the LTS we analysed, which can be used to inform future iterations of the documents.

Although we have taken a systematic approach to designing the assessment framework and recording information from the G20 members' LTS, it is possible that some discrepancies arose in the process of standardising information from diverse documents. LTS have no standard scope or format and some interpretation was required while making assessments. Our results should be interpreted as aggregated observations based on cross-cutting analyses. While we do note non-exhaustive country examples and exceptions in the text, we do not intend to rate or compare the G20 members' LTS.

The rest of the report is structured as follows. → **Section 3** presents our analysis on the overarching enablers for LTS implementation, including topics like technology innovation, climate finance, and capacity building, providing complementary information for the sections that follow. → **Section 4** discusses the role of adaptation in LTS. → **Section 5** looks at mitigation, the topic most extensively covered across LTS, and presents results on headline targets, energy and end-use sectors targets and plans, and residual emissions. Throughout the sections, we present recommendations for the improvement of future LTS submissions or for cooperation among countries.

03 KEY ENABLERS: TECHNOLOGY, FINANCE, AND CAPACITY BUILDING

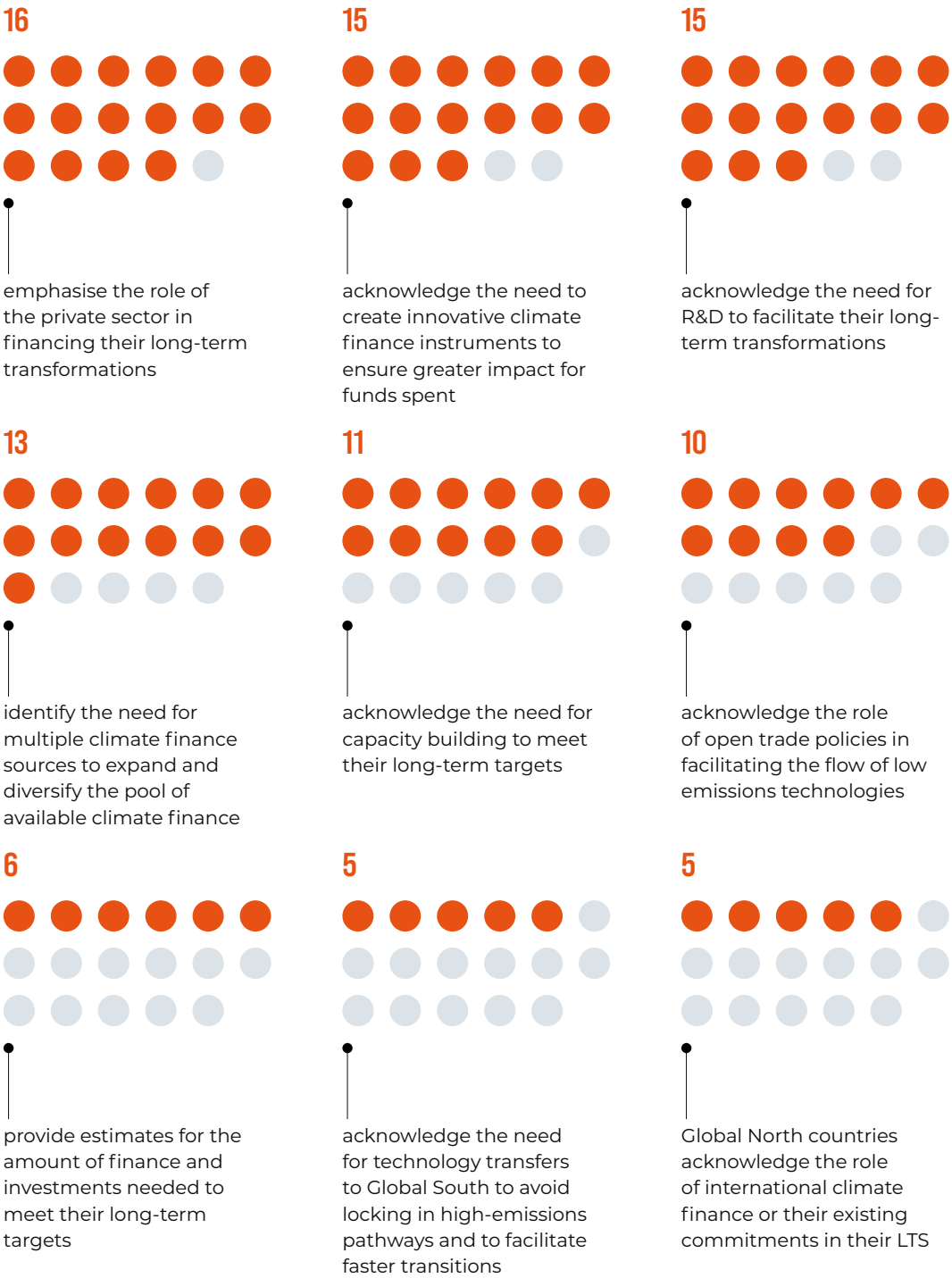


Figure 1

Number of LTS acknowledging key enablers, including technology innovation, climate finance, and capacity building

Based on our analysis, we identify an opportunity for countries to cooperate internationally on research and development (R&D) of key technologies. Fifteen out of 17 LTS we analysed acknowledge the need for R&D in key technologies crucial for their long-term transformations, and many explicitly identify it as a priority and international cooperation area. Key technologies identified across LTS as high priorities for R&D include clean hydrogen, carbon capture and storage (CCS), carbon removal technologies (natural and engineered), low-emissions steel, offshore wind, solar photovoltaics (PV), lithium-ion batteries, sustainable biofuels, super-efficient appliances, and low-carbon agriculture methods. Some of these are breakthrough technologies that have yet to achieve commercialisation, and international cooperation in their R&D can go a long way in accelerating cost reductions and facilitating knowledge sharing (IEA et al., 2022).

International R&D partnerships should encourage increased participation from Global South countries to facilitate equitable access to latest technologies. International partnerships are based on sharing the risks and benefits of investing in cutting-edge technologies, and participating countries get access to eventual technology innovations without facing intellectual property issues (IEA et al., 2022). Some G20 members' LTS (e.g., Australia, UK, India) highlight examples of existing bilateral and multilateral partnerships that support research, development, demonstration, deployment, trade, and supply chains of low emissions technologies or hard-to-abate sectors, such as Mission Innovation, Clean Energy Ministerial, and Leadership Group for Industry Transition (LeadIT). However, only about 17-21% of the current membership of these initiatives is composed of Global South countries (CEM, 2023; LeadIT, 2023; MI, 2023).

RECOMMENDATION

Countries should cooperate internationally to create inclusive R&D partnerships for key technologies to enable technology co-development and facilitate commercialisation and cost reductions. Ensuring adequate representation of Global South countries in such partnerships would ensure equitable access to both R&D investments and latest technology innovations.

We observe that G20 members do not often quantify the amount of climate finance required to achieve their LTS goals. While most G20 members acknowledge the role of climate finance, only six of the 17 we analysed include quantitative estimates in their LTS (Australia, the EU, France, India, Russia, and the UK). Similarly, we found that while seven G20 members (Argentina,

We define climate finance in this report as all financial flows targeted for climate adaptation or mitigation measures, including from public, private, international, and blended finance sources. Climate finance as defined here is not necessarily concessional.

Australia, China, India, Indonesia, Mexico, and South Africa) express the need for international climate finance sources to support their long-term transformations, only one country (India) quantifies these needs.

We identify a further lack of detail on how adequate climate finance will be mobilised for their long-term transformations. Thirteen of the 17 G20 members that we assessed identify the need for multiple climate finance sources (private, public, international) to expand and diversify the pool of available climate finance; eight of them also explicitly consider this to be a priority area. Fifteen G20 members also acknowledge the need to create new climate finance instruments (e.g., carbon pricing mechanisms, sustainable finance instruments, publicly funded incentives) to make climate mitigation and adaptation projects commercially viable and mobilise private finance. However, further details on developing such instruments or mobilising diverse finance sources (e.g., with de-risking support, policy incentives) are not always provided.

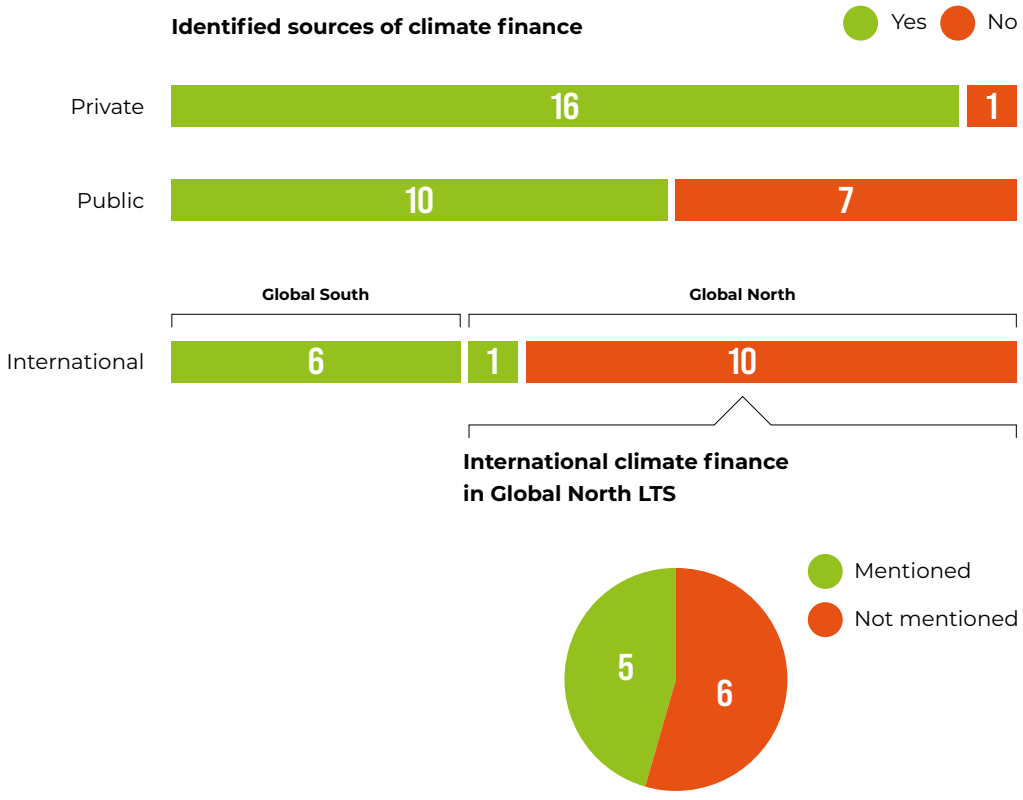


Figure 2

Bar chart: Sources of climate finance identified by G20 members

Pie chart: Mention of international climate finance in the LTS documents of Global North members

RECOMMENDATION

Countries should estimate their climate finance needs and outline a long-term investment plan in their future LTS. This would provide an indication of the scale of financing needs across countries, provide crucial policy signals for private investors, and enable assessment of the sufficiency of global financial flows.

We observe that Global North countries do not mention the general role of or their commitment to provide international climate finance in their LTS. Among the 11 Global North countries we analysed, only five (Australia, France, Germany, Japan and the UK) mention existing commitments or an intention to provide international climate finance to Global South countries. The remaining six do not mention the role of international climate finance at all (Canada, the EU, Italy, Russia, South Korea and the USA) **(→ Figure 2)**. Some of them (Canada, EU, Italy and South Korea) have recently announced international climate finance commitments separately; however, these are not mentioned in their LTS (Abnett, 2021; Reuters, 2021; CNN Group, 2023; IFC, 2023).

On the other hand, six out of the seven G20 members (Argentina, China, India, Indonesia, Mexico, and South Africa) that express the need for international climate finance in their LTS are Global South countries. Two of these (Argentina and India) also mention that the nature of climate finance being provided should be such that it does not increase debt burden on Global South countries and should incorporate concessional terms.

The lack of mention of international climate finance in LTS does not align with the principles of the Paris Agreement. While there are no specific, internationally-adopted guidelines on the structure and contents of an LTS, it is provided under Article 4 of the Paris Agreement that countries should develop their LTS "mindful of Article 2 taking into account their common but differentiated responsibilities and respective capabilities, in the light of different national circumstances" (UNFCCC, 2015). In this context, it is appropriate for G20 members to acknowledge and integrate into their long-term planning the role of international cooperation for mobilising the scale of financing required to achieve long-term transformations in the Global South.

RECOMMENDATION

Global North countries should better integrate international climate finance in their long-term planning. This would ensure that international financial commitments are acknowledged, quantified, and properly reflected in their overall climate budgeting, thus ensuring accountability on these commitments. Such documentation would also ensure transparency in terms of the nature of international climate finance and the level of concessionality being offered.

Finally, we observe that while G20 members acknowledge the need for capacity building, they do not identify specific needs or opportunities for international cooperation in this area. Eleven out of 17 G20 members mention the need for capacity building in their LTS, but a negligible few identify exact capacity needs or mention it as a cooperation area. Australia is the only G20 member that mentions providing support to Global South countries on capacity building. Countries could potentially benefit from international cooperation on capacity building programmes designed for sharing existing best practices, particularly if mutual capacity needs exist in areas like sustainable finance, low emissions technologies, and emissions or investment needs modelling.

RECOMMENDATION

Countries should identify specific capacity building needs in their future LTS and cooperate internationally on programmes addressing common needs. International cooperation on capacity building programmes addressing mutual needs can facilitate sharing of existing best practices and help countries achieve greater impact by pooling resources.

04 ADAPTATION AND LOSS AND DAMAGE

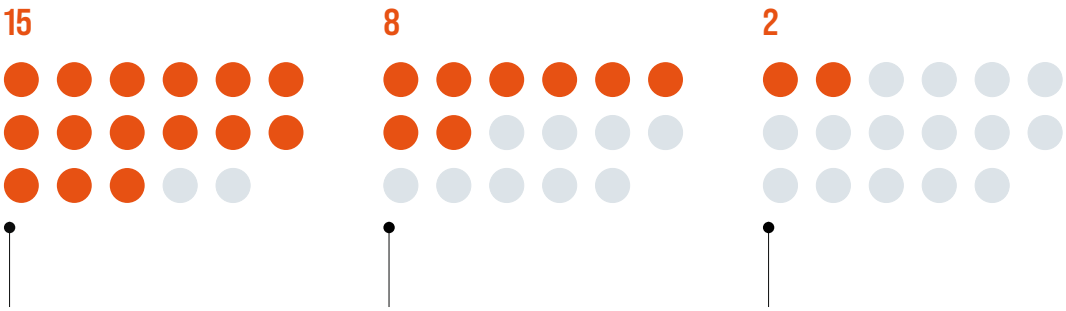


Figure 3

Number of LTS that discuss climate impacts and adaptation finance, and that mention loss and damage

Our assessment reveals limited references to concrete adaptation targets and measures in G20 members' LTS, despite a general recognition of climate impacts and the need for adaptation. Fifteen of 17 G20 members discuss climate impacts for their respective countries in their LTS, referring to rising temperature, extreme weather events (severe droughts, floods, forest fires, typhoons and hurricanes, and sea level rise), infrastructure risks (coastal cities, energy, and industry infrastructure), economic and productivity impacts (related to agriculture and oceans), and health risks (rise in infectious diseases) **(see → Figure 3)**. However, only eight of 17 G20 members outline targets or objectives for adaptation and recognise it as a priority area. Among those, only four G20 members (Indonesia, Mexico, South Africa and the UK) present specific and concrete targets, whereas the remaining only highlight broad objectives or plans for adaptation (Argentina, the EU, France and Japan). One reason for the absence of adaptation targets in the majority of LTS could be that countries consider it to be a mitigation-focused document.

Across LTS, we observe four broad themes concerning adaptation measures: 1) enhancing the resilience of communities, cities, and terrestrial and marine ecosystems, 2) reducing vulnerability to economic damages from climate disasters, 3) enhancing access to basic necessities (energy and water), and 4) establishing adaptation planning and risk management regimes.

RECOMMENDATION

G20 members should refer to concrete adaptation targets and measures in future LTS submissions. Including details on adaptation efforts in LTS can help countries to prioritise and collaborate on mutually reinforcing mitigation and adaptation strategies.

We also observe limited mentions of adaptation finance needs in G20 members' LTS. Only eight of the 17 G20 members discuss the role of adaptation finance (Argentina, Australia, the EU, France, India, Indonesia, South Africa

and the UK), of which seven (all except Australia) acknowledge it as an area of international cooperation **(see → Figure 4)**. Only one member (India) has quantified its financial needs for adaptation, though these are inclusive of SDG and basic needs. Australia, France and the UK explicitly acknowledge their role in supporting resilience and adaptation efforts at regional or international levels, with the UK's LTS presenting concrete targets of doubling their international climate finance between 2012 and 2025. While international flows to developing countries have risen slowly, the adaptation finance gap continues to widen (United Nations Environment Programme, 2022). Adaptation needs are five to ten times greater than finance flows.

RECOMMENDATION

G20 members should specify their finance needs for adaptation efforts in future LTS. This will be a first step to ensuring that adequate climate finance flows towards adaptation.

We identify a further lack of acknowledgement of loss and damage in future LTS. India and Indonesia are the only two countries that mention "loss and damage" in their LTS **(see → Figure 3)**. While Indonesia outlines that rising sea surface temperatures will cause loss and damage to ecosystems, India states that developing countries need to get financial compensation for unavoidable loss and damage. Climate change has already caused losses and damages, and these will continue to increase (IPCC, 2023). At COP27 in Egypt, countries agreed to establish a fund to compensate the most vulnerable countries for "loss and damage" from climate-related disasters. In future LTS submissions, countries could therefore provide details on the financial compensation they plan to provide or explain for what losses and damage they expect compensation.

RECOMMENDATION

G20 members could provide details on loss and damage in future LTS. Countries that are most vulnerable and impacted by climate change should describe the extent of loss and damage they face and include financial needs in future LTS. This would provide an indication of the scale of compensation needs. In addition, the countries that will pay into the Loss and Damage Fund should include details on the financial compensation they reserve for compensation. This would send a signal to other countries, especially those most affected by climate change, that the world's strongest economies follow up on the agreement to establish a special fund for loss and damage.

05 MITIGATION

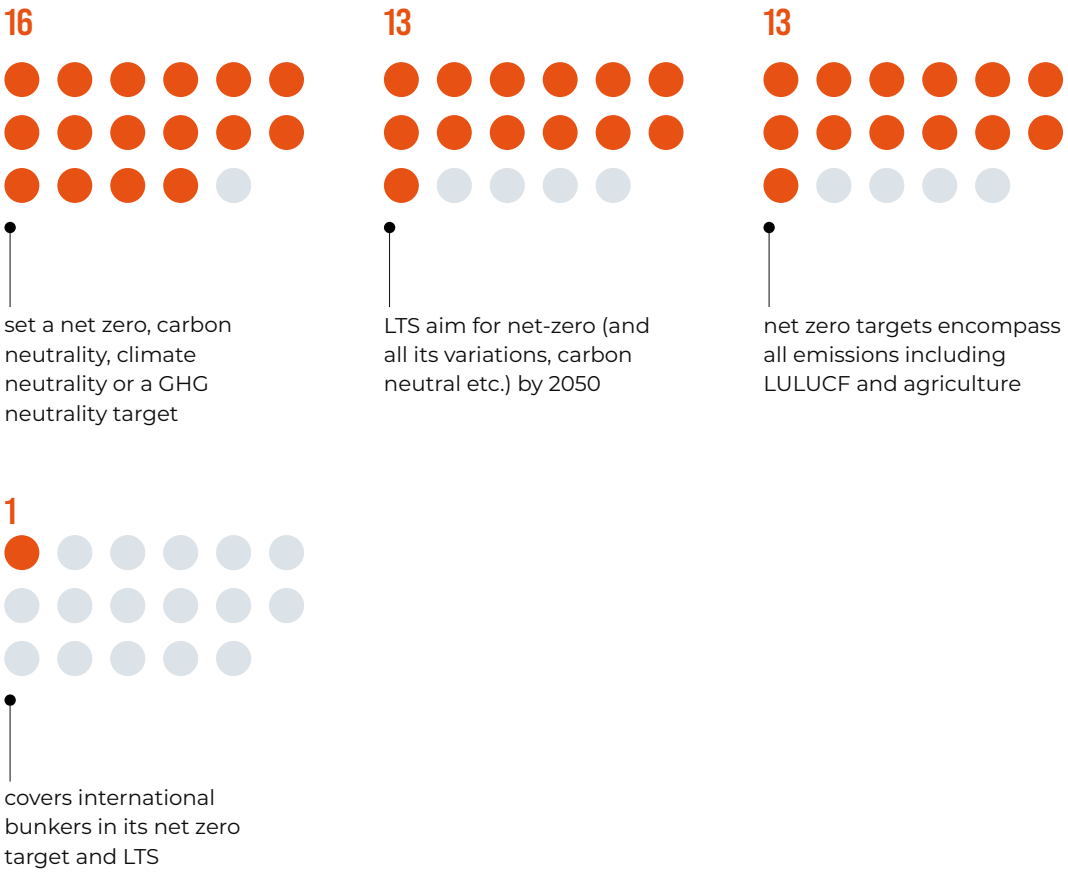


Figure 4

Number of LTS with a net zero commitment and details on target year, GHG coverage and inclusion of international bunkers

5.1 HEADLINE TARGETS

We observe that G20 members do not always explicitly define the scope and coverage of their headline targets. Eight of the 17 LTS (Australia, Canada, India, Indonesia, Russia, South Africa, UK, US) mention 'net zero' targets, while others utilise terminologies like 'carbon neutrality' (China, France, Germany), 'climate neutrality' (EU, Italy, Japan, South Korea), and 'GHG neutrality' (Argentina) **(see → Figure 4)**. Mexico is the only country we assessed that does not set a net zero or neutrality target in its LTS, but instead formulates emissions reduction targets. The use of various terminologies to formulate headline targets and the lack of standard definitions for these terms leads to ambiguity on what exactly is covered or omitted by each. For example, the difference between climate neutrality and GHG neutrality is unclear.

Further, thirteen G20 members (Argentina, Australia, Canada, the EU, France, Germany, Indonesia, Italy, Japan, Mexico, Russia, the UK and the USA) explicitly mention that their headline targets cover all GHGs, including those from LULUCF

and agriculture **(see → Figure 4)**. Emissions from LULUCF and agriculture can be difficult to quantify and model, explaining why some G20 members may not include them. LULUCF emissions in particular could contribute positive or negative emissions depending on the country context and are therefore crucial in assessing progress towards net zero.

Similarly, only the United Kingdom states that international bunkers are covered by its net zero target, while the European Union includes international aviation but not international shipping in its climate neutrality target **(see → Figure 4)**. Germany, Italy, Russia, and the United States explicitly state that international shipping and aviation are not covered by their net zero targets, while the other LTS assessed make no reference to the inclusion of international bunkers. International shipping and aviation are responsible for 3% of global CO_2 emissions (Liu et al., 2023) and emissions in both sectors are projected to increase in the coming decades (CAT, 2022, 2023). The uncertainty regarding coverage of emissions from international bunkers thus represents a blind spot in current net zero target formulations, posing a significant challenge to achieving global net zero by 2050.

RECOMMENDATION

G20 members should set net zero targets that cover all GHGs and economic sectors. Some G20 members do not clearly define the scope and coverage of their net zero commitment, which hinders a proper assessment of target sufficiency and reporting on global progress. As a first step, it is critical that countries clarify their existing net zero commitment. Further, G20 members should expand their net zero targets to cover all GHGs and all economic sectors, including international aviation and shipping.

Three of 17 G20 members (EU, France, and Italy) explicitly state in their LTS that their net zero targets do not rely on international offset credits, and that these are domestically achievable. Australia states that it will source emission reduction credits from abroad, while the other G20 members either keep the possibility of using international offset credits open or provide no information on the matter in their LTS. To stand a reasonable chance of limiting global warming to 1.5°C, global emissions must reach net zero by 2050 (IPCC, 2023). Any country that relies on reductions or removals from other countries to achieve their targets places a burden on other countries to go beyond net zero and realise net negative emissions (Climate Action Tracker, 2021). Further, countries that aim for net zero emissions through international offset credits risk locking in domestic fossil fuel infrastructure and not achieving their net zero target if international offset credits turn out unavailable by 2050 (Kachi et al., 2019).

RECOMMENDATION

G20 members should note whether they plan to mitigate emissions within their borders or use international offsets to meet their net zero commitments. This information is critical to understand the real ambition of net zero commitments.

Reducing global GHG emissions to net zero by 2050 requires some countries to decarbonise faster to balance out residual emissions from countries that will only reach net zero in the second half of this century. Twelve of the 16 G20 members with net zero commitments aim to achieve their targets by 2050, whereas Germany aims for 2045, China and Indonesia for 2060 and India for 2070 **(see → Figure 4)**. While Global North members of the G20 have peaked their emissions already, emissions from the Global South members are on the rise. This means that the transition needs to happen at a much faster pace in countries like China and India than in countries like the United Kingdom and the United States. Keeping in mind the principle of CBDR-RC, it is key that Global North countries decarbonise their economies earlier than 2050 and provide technical and financial support to the Global South to ensure that those countries can reach net zero earlier than their current targets.

RECOMMENDATION

G20 members should collectively enhance their net zero ambition. Global North members should target aim for an earlier 2050 net zero target so that Global South members have more carbon space to meet their developmental priorities keeping CBDR-RC at the core.

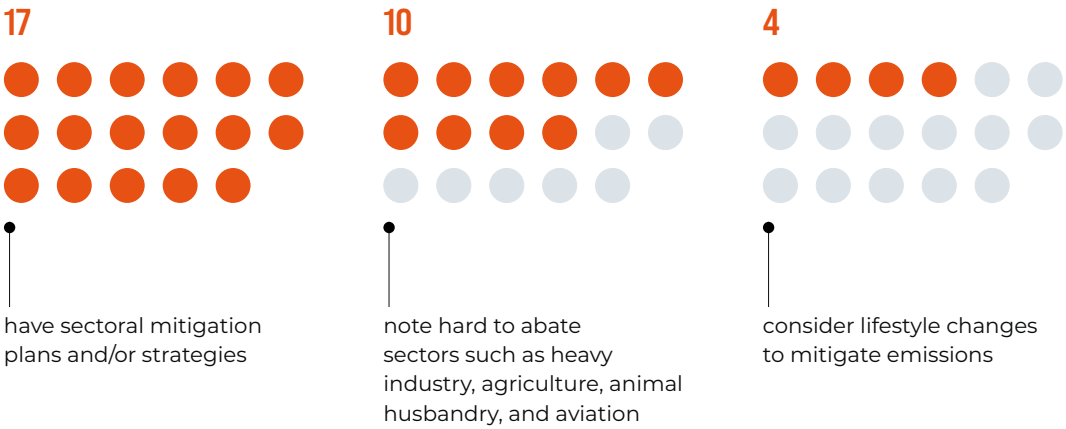


Figure 5

Numbers of LTS that outline sectoral targets and plans, identify hard-to-abate sectors, and consider lifestyle changes as a reduction measures

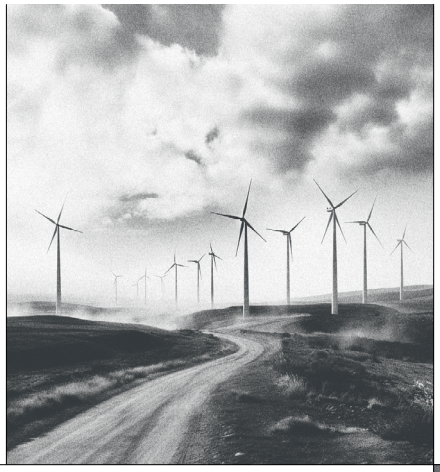
5.2 OVERVIEW OF SECTORAL TARGETS AND MEASURES

We observe that while all G20 members have outlined targets and/or plans for some sectors in their LTS, they do not often provide both or cover all sectors (see → Figure 5). Only ten out of the 17 LTS assessed provide sectoral decarbonisation targets and associated plans. Sixteen countries noted power and buildings as priority sectors for decarbonisation, 15 mentioned industry and agriculture, fisheries and forestry, 13 mentioned transport and buildings, and ten mentioned the waste sector **(see → Figure 7)**. Of the 17 LTS assessed, 10 provide what sectors they consider hard to abate, notably heavy industry, agriculture, animal husbandry and aviation **(see → Figure 5)**.

→ **Figure 6** lists the mitigation measures that we identified in the 17 LTS. Some of the commonly mentioned measures across different sectors include: a shift towards renewable energy, utilisation of (clean) hydrogen, demand side electrification and energy efficiency improvements and enhancing natural sinks. → **Box 1** discusses the sectoral plans that the 17 G20 members outline in their LTS.

POWER

Shift towards renewables (wind, solar); CDR technologies; storage targets; affordable electricity; geothermal, hydro, nuclear energy; smarter and flexible grid; financial incentives for rooftop solar; transformation of the financing system of the sector; investments in reducing pollution from power plants; reducing energy waste.



INDUSTRY

Energy efficiency; electrification; (clean) hydrogen; industrial energy management system; supply of sustainable raw materials; bioenergy.

TRANSPORT

Zero-Emission Vehicles (ZEVs); electrification; public charging infrastructure; alternative fuels; modal shift towards public transport and NMT (non-motorised transport); rail freight; digitalisation; electricity use in the air and maritime transport; behavioural changes and financial incentives.

BUILDING

Appliance energy efficiency improvements; refurbishment/retrofitting of existing building stock; electrification of heat pumps and boilers; smart buildings management systems; insulation material improvements; district heating within neighbourhoods.

AGRICULTURE, FISHERIES & FORESTRY

Preserving/expanding natural carbon sink; improving crop productivity; fertilizer emissions reduction; organic and integrated farming reduced livestock holdings; avoiding food waste; agronomic methods; biofuel production; maintaining water balance of swamps.

WASTE

Circularity; sustainable urban development; 3 Rs (reduce, reuse, recycle); improve recovery of metals and energy; industrial and waste-water treatment plants.

LIFESTYLE EMISSIONS

Nudges towards energy-efficient behaviour through campaigns, programmes; influencing consumer behaviour by visualising CO_2 emissions.

Figure 6

Overview of measures presented in the 17 LTS

Measures that were mentioned in various LTS are highlighted in bold

Box 1

Examples of sectoral measures in the 17 LTS

POWER

Sixteen of the 17 G20 members assessed discuss and prioritise power sector mitigation plans in their LTS. Decarbonising the power sector is critical to decarbonising most other economic sectors. Out of the global increase in emissions in 2021, electricity generation accounted for 46% of the total emissions (IEA, 2022). Mitigation plans mostly focus on developing storage systems and integrating renewable energy into the grid, aiming towards a smarter, flexible and affordable grid. Some countries suggest ways of improving flexibility, South Korea, for instance, mentions the utilisation of coal power plants with CCUS as power backup **(see also → Section 5.3.2)**, while the United Kingdom reports the use of hydrogen to generate electricity to avoid the use of natural gas. While all countries have mentioned the utilisation and shift towards conventional renewable sources of electricity generation such as solar and wind, some provided examples of unconventional sources. Italy, for instance, plans to explore geothermal energy further. Countries also communicate the challenges to the power sector transformation, either through direct statements or indirect indicators. For example, Germany mentions balancing demand and supply with affordability as a challenge and provides efficient smart grids as a solution. Mexico, on the other hand, addresses lack of investments indirectly by mentioning that their energy reform has simplified interconnections between power plants and high potential renewable energy projects to promote investments.

INDUSTRY

Fifteen of the 17 G20 members consider the industry sector as a priority area in their mitigation efforts. Industry is the world's second largest emitting sector and accounted for 25% of global emissions in 2021 (IEA, 2022). China, France, Germany, Japan, Mexico, and South Korea, emphasise the need to redesign industrial processes by promoting highly efficient technologies, fuel substitution, and CO_2 capture technologies in energy-intensive industries such as cement, steel, petroleum, chemical, and petrochemical industries. The imperative to decarbonise heavy industry is increasingly pronounced across all countries. For example, Australia has been actively supporting R&D efforts to advance clean hydrogen technologies and infrastructure.

BUILDINGS

Sixteen of the G20 members refer to mitigation plans or targets for the building sector, with 13 considering it a priority area. Globally, buildings constituted 8% of the total energy sector emissions in 2021(IEA, 2022). As a priority area, the LTS mainly focus on electrification of the sector, improving energy efficiency standards, appliance energy efficiency labelling, updating and implementing new sustainable building codes, or retrofitting older building stock. Some G20 members provided plans for mitigation, such as Canada's Greener Homes Loan Program which will support communities to upgrade and retrofit homes and buildings. Others also provided sector-specific targets for example; France plans to reduce emissions from the buildings sector by 49% by 2030 compared to 2015.

TRANSPORT

Thirteen of the 17 LTS assessed consider transport a priority area. The transport sector was responsible for 37% of global CO_2 emissions in 2021 (IEA, 2022). All 17 LTS identified electrification a significant step to decarbonise the transport sector. In addition to that, almost all of the 17

LTS note the importance of low and zero emission vehicles (ZEVs), alternative fuels, supporting rail freight, digitalisation, behavioural changes, and the necessary charging infrastructure. For example, the US highlights the need to ramp up research, development, demonstration, and deployment of lower carbon fuels, such as clean hydrogen and sustainable biofuels, to decarbonise end-uses that cannot be directly electrified, such as aviation, marine transportation, and some trucking segments. However, Indonesia believes that sociocultural practices, lifestyles, and social status affect transport, therefore it has taken a more comprehensive approach on the demand side management. Indonesia's breakdown of the transport sectors' energy demand in 2050 is low-carbon energy mix comprising biofuels (46%), oil fuels (20%), electricity (30%) from RE and natural gas (4%).

AGRICULTURE, FISHERIES AND FORESTRY

Fifteen of the LTS assessed consider agriculture a priority area and highlight the need to expand natural carbon sinks, promote land-based solutions, and other emerging technologies. For example, Germany targets expanding organic farming, the use of more efficient nitrogen fertilisation, and reducing livestock holdings. Russia, on the other hand, intends the use of alternative agronomic methods (regenerative technologies) that increase yields and promote more intensive absorption of residual carbon. Russia also promotes the production of biofuels in livestock and crop production and introduces the use of biogas complexes for the disposal of organic waste, ensuring the accumulation of carbon in the soils of agricultural lands. Additionally, the UK aims to decarbonise the agriculture sector by providing funding to support farmers to take up low carbon practices and technologies.

WASTE

Ten of the 17 LTS assessed highlight waste as a priority area with the central theme to develop a circular economy. For instance, South Africa and Japan provide a comprehensive strategy to build a circular economy by promoting the "three R's (reduce, reuse, recycle). Japan also emphasised plans to improve the recovery of metal and energy through heat utilisation by waste power generation and the recovery of methane from raw waste. Additionally, it aims to introduce artificial intelligence technology in this sector to enhance waste management processes and improve overall efficiency. Addressing emissions from the waste sector is critical, as the sector is responsible for about 20% of human-driven methane emissions globally (Siegel, 2022).

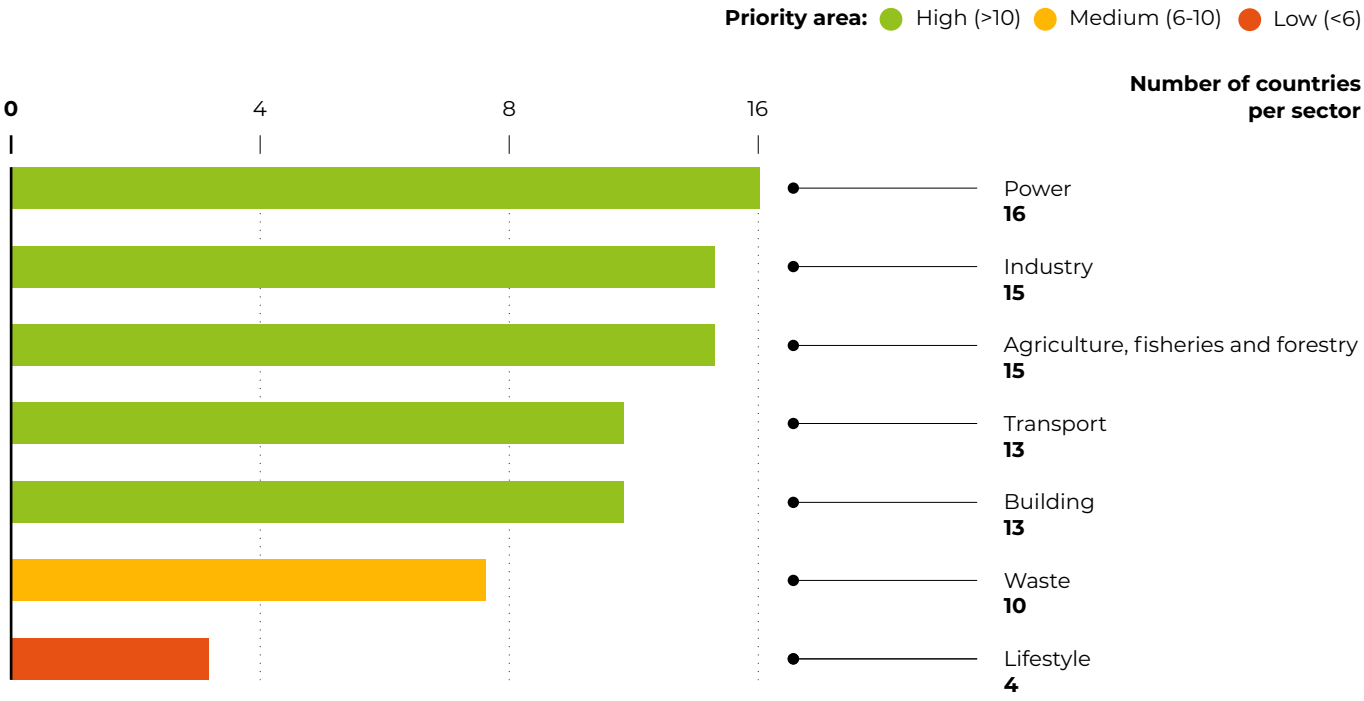
RECOMMENDATION

G20 members should outline targets and detailed plans for all economic sectors in their future LTS submissions. Different sectors contribute to emissions in varying degrees and have distinct opportunities for mitigation, and sectoral targets thus allow for a more focused approach for emissions reduction.

We also observe that G20 members do not emphasise the role of sustainable consumption of goods and services in achieving mitigation targets. Only four G20 members (France, India, Japan, and Mexico) considered it as a priority **(see → Figure 7)**. India emphasises on the mission 'Lifestyle for Environment' (LiFE) aimed at a global mass movement nudging individual behaviour from "mindless and destructive consumption" to "mindful and deliberate utilization." France highlights a large-scale social change in favour of the climate and energy transition, notably through the promotion of more moderate lifestyles and consumption patterns. It has also developed and disseminated digital tools that enable citizens to calculate their own impact on the climate, and that propose personalised emissions reduction actions tailored to individual lifestyles. While some of the LTS refer to the need for changes in lifestyle patterns, none mention this is a key measure in reducing emissions from agriculture and international aviation. However, science indicates that a shift to plant-based proteins and a reduction in demand for aviation is vital to limiting emissions in those sectors (Willett et al., 2019; Creutzig et al., 2022). (IPCC, 2023)

RECOMMENDATION

G20 members should recognise the role of behavioural changes and sustainable consumption in mitigating emissions and focus on sharing best practices with other countries. Scientific evidence demonstrates that lifestyle and behaviour changes could lead to a remarkable 40-70% reduction in greenhouse gas emissions by 2050 (IPCC, 2023).



We identified power, industry, agriculture, fisheries and forestry, transport, and building sectors as "high priority" across LTS. We classify a sector as "high priority" across the LTS if over 10 LTS considered a sector a priority; if six to 10 countries defined a sector as a priority, we categorised as a "medium" priority; and if fewer than six countries considered a sector a priority, we categorised it as "low" priority.

Figure 7
Overview of priority areas across the 17 LTS

5.3 DECARBONISING THE ENERGY SECTOR

5.3.1 EXPANDING CLEAN ENERGY AND ENERGY EFFICIENCY

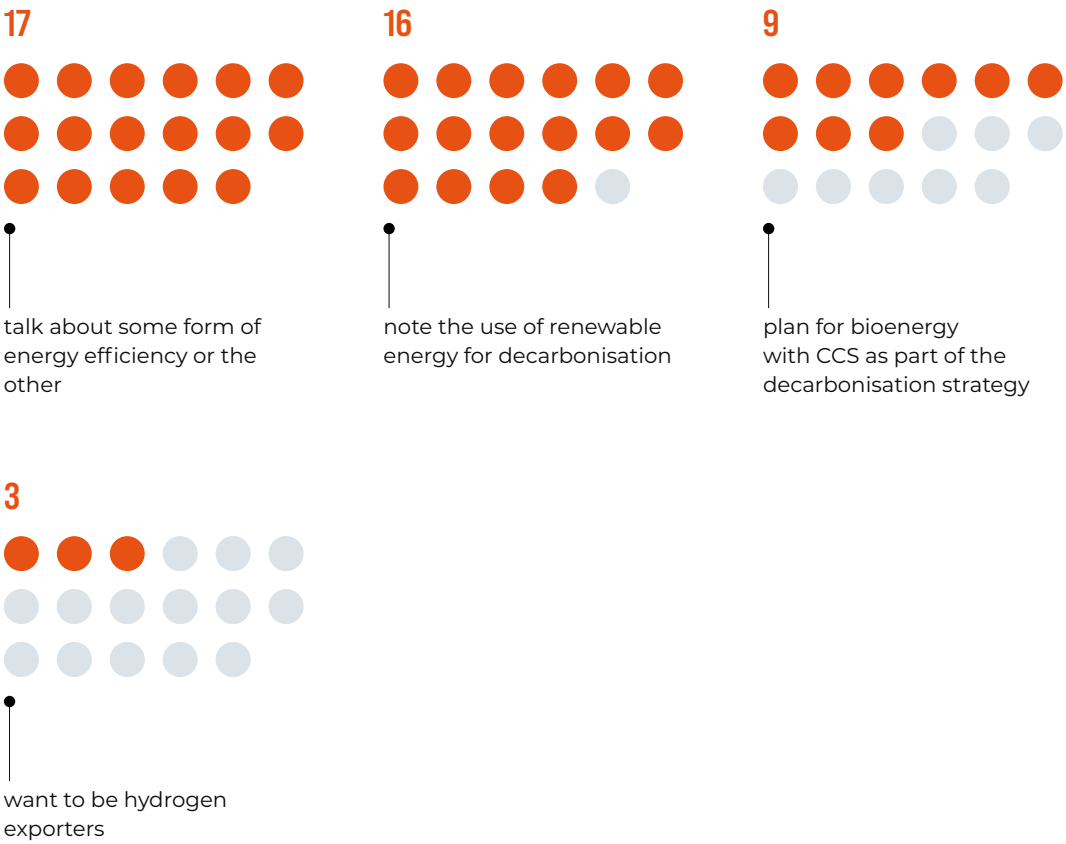


Figure 8
Number of LTS referring to energy efficiency, renewable energy, bioenergy with CCS and hydrogen export ambitions

As discussed in → **Section 5.2**, energy efficiency, renewable energy, hydrogen, nuclear and bioenergy are commonly mentioned by G20 members as key measures to decarbonise their energy systems. This section outlines to what extent the 17 LTS assessed provide details on these measures.

ENERGY EFFICIENCY

We observe that all countries mention decarbonisation plans focused on energy efficiency measures, but not many provide concrete targets (see → Figure 8). Only five G20 members (EU, Italy, Japan, South Africa and the UK) provide targets on improving energy efficiency. The LTS of the 17 G20 members mention energy efficiency improvement across sectors, including building, industry, transport, power generation and agriculture. Yet, the predominant focus is on the building and industry sectors as the LTS explicitly highlight retrofitting, standards for energy efficient buildings, and appliance ratings and technological developments.

RECOMMENDATION

Countries should focus on mainstreaming energy efficiency plans and set ambitious targets. Having robust energy efficiency plans and targets will help in reducing energy demand of the end-use sectors such as building, industry and transport.

RENEWABLE ENERGY

We find that renewable energy deployment is mentioned by all G20 members (except Argentina) as part of their decarbonisation strategy, but not all mention renewables-specific targets (see → Figure 8). Four countries (Australia, Canada, Indonesia, and Russia) mention renewable energy in their LTS, but do not provide any concrete targets. India and Mexico set targets for the non-fossil share in electricity generation (50% installed capacity) and clean energy resources (40% of power generation), respectively, which includes nuclear power. USA provides targets for average annual total capacity additions for three decades (2020-30, 2030-40, 2040-50) with and without storage for clean energy.

Nine G20 members - China, EU, France, Germany, Italy, Japan, South Africa, South Korea and the UK - note exclusive renewable energy targets, but they vary vastly in terms of its expression. For example, the UK explicitly mentions deploying 40 gigawatts (GW) of offshore wind by 2030, Japan notes 10 GW by 2030 and 30-45 GW by 2040 of floating offshore wind, while South Africa provides a GW target for solar PV 6.8 GW, wind 15 GW, hydro 2.5 GW and CSP 0.3 GW. Yet, China defines its renewable energy target as a share of fuel mix for electricity generation of 7.5%-10% by 2035, and to 15% subsequently. Similarly, the EU notes 80% of electricity will come from renewables by 2050, while Germany mentions almost all electricity from renewable energy by 2050. Further, Italy and France note their renewable energy target as a percentage of their final energy consumption and South Korea notes renewables as a percentage of energy production.

Examples of renewable energy policies mentioned in the LTS are provided in → **Box 2**. While renewable energy technologies provide an alternative to decarbonisation, there are risks associated with land footprint as well as the tonnes of waste that renewable energy technologies generate (Tyagi et al., 2023). Countries should consider and pre-empt these.

Box 2

Overview of renewable energy policies and measures mentioned in the 17 LTS

Some of the G20 members noted the potential use of renewable energy across various sectors, including, power, transport, buildings and industry. For the rapid uptake of renewable energy, the G20 members are putting infrastructure, technology, policies, market design and finances in place to meet those targets, for example:

- Australia is investing in transmission and distribution networks and microgrids.
- The EU is updating its energy market design, involving consumers, digitising, scaling up energy storage and demand side response.
- Germany reserves 2% of the federal territory for onshore wind energy by 2032, providing new sites for PV expansion, involving municipalities, improving policy environment for citizens to install rooftop solar,
- India is enhancing its renewable purchase obligation targets, supporting open access power purchases, building green corridors for transmission networks and enhancing policy and financial incentives for solar park development, accelerated depreciation on investment, amongst others.
- Italy is creating a flexible system with high-capacity storage and improving its network infrastructure,
- Japan is ensuring the stability of the grid with renewable energy and promoting energy storage systems from batteries and hydrogen and next-generation inverters and effective communication technologies.
- Mexico is strengthening its regulatory and institutional framework, using smart grids and distributed generation in the national electric system.
- South Africa is deploying a competitive tender process that is designed to incentivise renewable energy project development, amongst others.
- South Korea has a Renewable Portfolio Standard scheme that is increasing the mandatory renewable energy share and a Feed-in-Tariff-based subsidy programme for small-scale power producers.
- All 17 G20 members note various types of storage in their LTS, such as batteries, pumped hydro, thermo-chemical storage and vehicle batteries.

HYDROGEN

We observe that most countries view hydrogen as an important decarbonisation opportunity, but not many define the type of hydrogen they plan to utilise. Fifteen G20 members reference hydrogen in their LTS, using terminologies like "low-carbon hydrogen" (Australia), "green hydrogen" (India), "carbon free hydrogen" (USA), and sometimes simply "hydrogen" (Japan). Argentina and Indonesia are the only G20 members assessed that do not mention hydrogen in their LTS. Australia, India and Russia state their ambition to become hydrogen exporters in the future, which would be an opportunity for collaboration **(see → Figure 8)**.

In their LTS, the G20 members highlight that hydrogen could be used to decarbonise the industry, transport, refining and power sectors. For instance, hydrogen could be used to reduce emissions from steel, iron and cement production to fuel aircraft and large ships, and to store energy. While hydrogen technology, both from the manufacturing side and the potential areas of demand, is in the early stages, access and processing of critical minerals and global supply chains for these will require collaboration in the form of common taxonomy to promote trade between countries. Establishing uniform regulatory standards to enable interoperability of green hydrogen technology is a possible method of bolstering collaboration (Tyagi et al., 2023).

RECOMMENDATION

G20 members should define the type of hydrogen mentioned in their LTS and collaborate on developing a standardised hydrogen taxonomy. For smooth trade and collaboration on hydrogen for decarbonisation, the definition of green, clean, low-carbon hydrogen needs to be standardised.

RECOMMENDATION

G20 members need to collaborate on diversifying 'critical minerals' supply chains to accelerate decarbonisation in the supply and demand side sectors. Supply of critical minerals needs to be secured to allow hydrogen, renewable energy and battery storage to scale up.

NUCLEAR

We observe that G20 members are divided on whether nuclear power will play a major role in long-term decarbonisation. While some G20 members have noted the role of nuclear, others have taken a position to progressively reduce nuclear while some others have not even mentioned nuclear at all. South Korea and Germany plan to progressively phase out nuclear energy, while India and China plan to ramp it up. France, which currently generates 68% of its electricity with nuclear power (US EIA, 2023) plans to decrease that share to 50%. Further, Argentina, Indonesia, South Africa and Italy do not mention nuclear energy as a decarbonisation option. While nuclear energy does not have emissions associated with it, there is a need to sustainably manage water demand, safety, and disposal of nuclear waste so that there are no eventualities.

BIOENERGY

While all countries plan to use bioenergy as part of their decarbonisation efforts, there is limited acknowledgement of sustainability issues around bioenergy. All 17 LTS either explicitly noted bioenergy as a decarbonisation measure, or implicitly mentioned it as part of their existing fuel blending policies. A variety of bioenergy types and applications are mentioned, including bioenergy from residues, biomass power generation, synthetic biofuels for aviation, and biodiesel. While bioenergy may play a role in decarbonising sectors that are difficult to electrify, such as aviation, there is very limited global potential for sustainable bioenergy (Calvin et al., 2020; ETC, 2021; Clarke et al., 2022). Large-scale bioenergy use has adverse sustainability impacts, including deforestation, food insecurity, biodiversity loss and water scarcity.

Nine G20 members (Australia, Canada, EU, France, Indonesia, Italy, Japan, UK and USA) also mention bioenergy with CCS (BECCS) as a strategy to achieve their net zero or emissions neutrality targets, given its ability to generate net negative emissions **(see → Figure 8)**. However, this technology is not yet proven at scale, poses sustainability risks, and accounting rules for BECCS are not well established. → **Section 5.4** discusses BECCS in more detail.

RECOMMENDATION

Countries should consider and address the sustainability impacts of bioenergy in their future LTS. Given the very limited availability of sustainable bioenergy, it is critical that countries limit their reliance on this energy source and try to pre-empt any negative impacts of bioenergy.

5.3.2 FOSSIL FUEL PHASE OUT

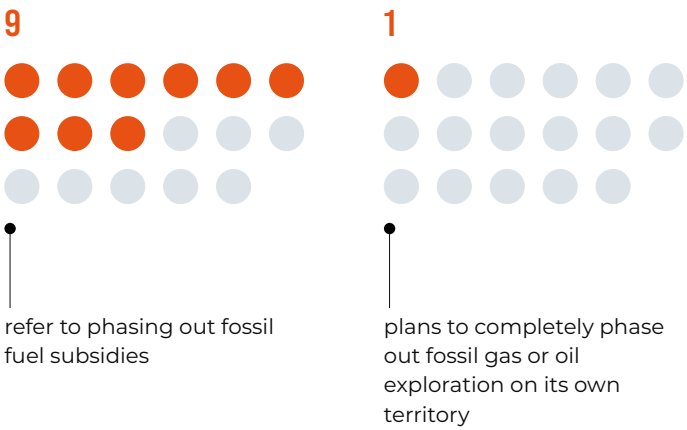


Figure 9
Number of LTS with commitments to phasing out oil and gas exploration on own territory and phasing out fossil fuel subsidies

We observe only a few mentions of commitments to phase out fossil fuels in G20 members' LTS, and these commitments are vaguely formulated. Energy security issues play a key role in the G20 negotiations, and the Russia-Ukraine war has created uncertainty around the world and slowed the pace at which some countries have decommissioned fossil fuel infrastructure. Although the phase out of fossil fuels is crucial for the transition to net zero, only four out of the 17 assessed G20 countries include a plan to phase out coal in their LTS: the EU (no end-date), France (coal phase out until 2022), Germany (2030), and the UK (2024). Except for France, most LTS remain vague on whether their coal phase out commitments cover only new or existing exploration on their own territory, or whether imports and financing of coal abroad are also affected.

Canada (2030) and Italy (2025) are members of the Powering Past Coal Alliance and have also committed to a coal phase out, but this is not mentioned in their LTS (PPCA, 2023). As mentioned in → **Section 5.2**, South Korea also states its intention to phase out coal power plants, but rather than shifting to renewable energy generation, the country plans to equip its coal power plants with CCS or convert them to LNG plants. Coal-fired power generation in combination with CCS does not amount to a coal phase out.

Sixteen of 17 LTS do not mention plans to phase out fossil gas or oil exploration (see → Figure 9). Only France refers to a ban for all new hydrocarbon exploration from 2018 onwards and to the phasing out of existing concessions by 2040, both on its own territory. In contrast, Australia explicitly commits to long-term coal and gas exploration "through to 2050 and beyond" in its LTS. While most of the other LTS do not provide concrete targets for phasing out fossil fuel exploration, several refer to plans to reduce dependence on fossil fuels over time, for instance Germany and the UK.

RECOMMENDATION

G20 members should formulate clear commitments or reaffirm their existing commitments to phase out fossil fuels in their future LTS. Setting clear targets would be the first step for G20 members to chart a trajectory for phasing out fossil fuels and consider how to ensure a just energy transition. It would also send a signal to private actors, which could spur investments in renewable energy and reduce the risk of carbon lock-in and stranded assets.

We found only vague statements on phasing out fossil fuel subsidies. Fossil fuel subsidies incentivise continued supply and use of fossil fuels, whereas a rapid shift to renewable energy is critical to staying below the Paris Agreement temperature limit (IEA, 2021). Nine G20 members (Canada, France, the EU Germany, Italy, Japan, South Africa, South Korea and the UK) mention phasing out fossil fuel subsidies, but do not specify which fossil fuels will be phased out or by when **(see → Figure 9)**.

Only four of the 17 LTS assessed consider the phase out of fossil fuel subsidies a cooperation area. The EU and South Africa refer to phasing out these subsidies in the G20 context, Japan in the G7 context and Germany makes a general statement to work on it at national, European, and international levels. Both the G7 and G20 have issued commitments on ending fossil fuel subsidies for decades, but these statements are non-binding and reports show that subsidies have even doubled since 2021 (IEA, 2023).

RECOMMENDATION

G20 members should set clear commitments on phasing out fossil fuel subsidies and cooperate internationally to shift public funding towards green technologies. Clear commitments on phasing out fossil fuel subsidies would send a strong signal to the market and discourage investments in fossil fuels. Countries can share best practices and lessons learnt on how to effectively end fossil fuel subsidies.

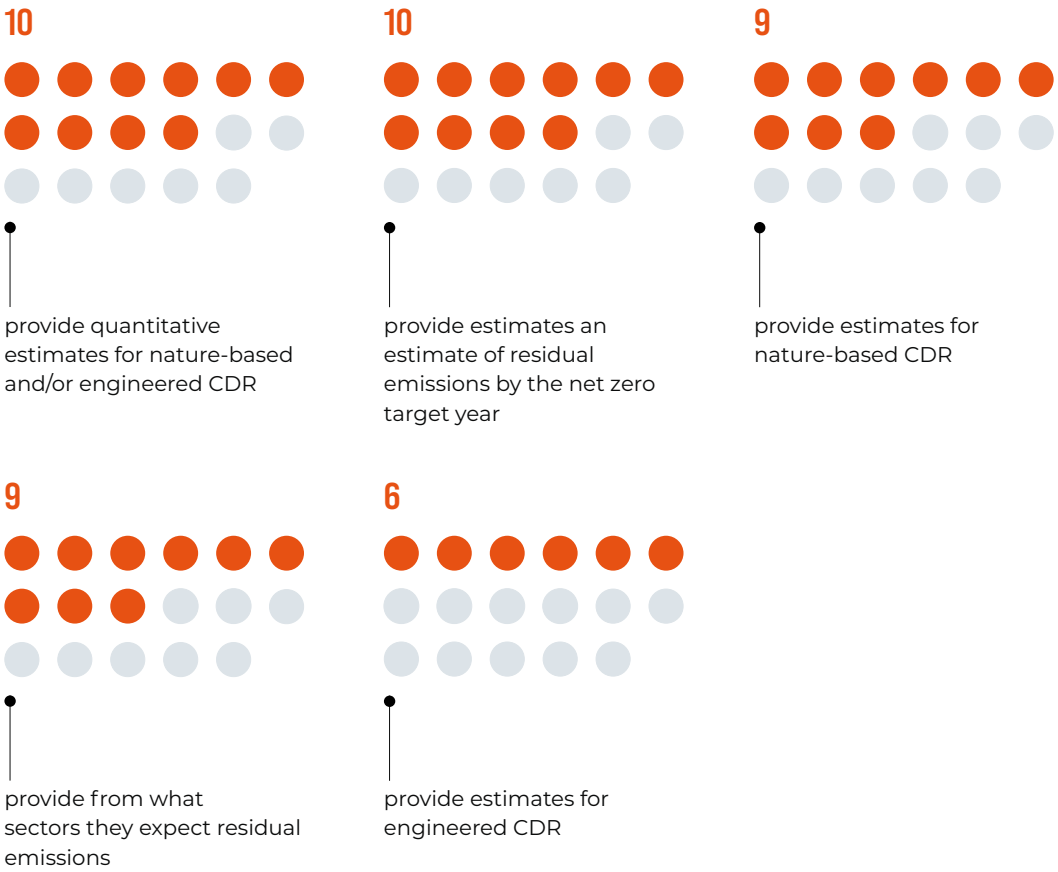


Figure 10

Number of LTS that provide estimates on residual emissions, LULUCF and engineered CDR

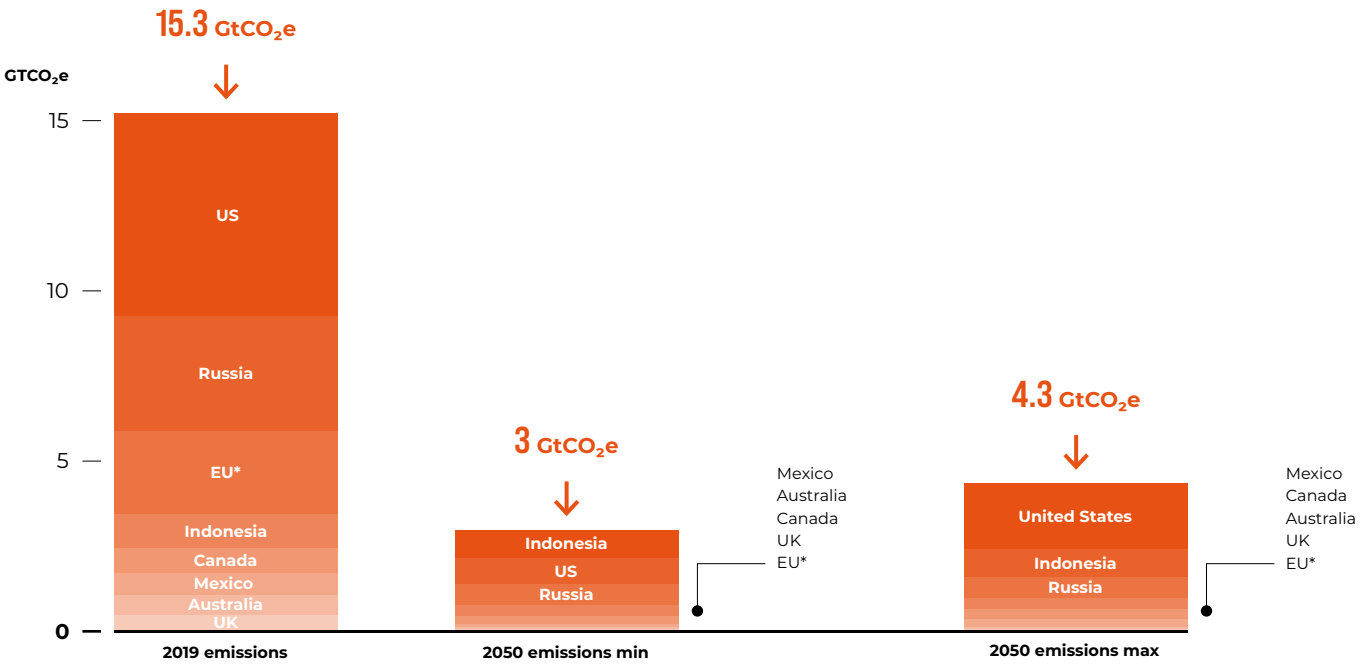
5.4. RESIDUAL EMISSIONS

Our assessment shows that the ten G20 members that provide details on residual emissions expect to reduce on average 72-81% of their 2019 emissions by 2050 (see → Figure 11). Residual emissions are those that are not eliminated, for economic or technological reasons (Buck et al., 2022). Governments need to balance these emissions out by CDR to achieve net zero. Some countries, however, plan to offset their residual emissions with reductions or removals in other countries (e.g. Australia). Therefore, countries may provide different numbers for their residual emissions and domestic CDR assumptions. The ten G20 members that provide estimates on residual emissions by 2050 in their LTS, expect to have joint residual emissions of at least 3 gigatonne (Gt) CO_2e but possibly 4.3 GtCO_2e in 2050 **(see → Figure 10, → Figure 11 and → Annex 2)**. This corresponds to 19-28% of their 2019 emissions, which implies the need for substantive carbon removal efforts.[1] If all countries were to reduce their 2019 emissions by 71-81%, the global sustainable potential for nature-based CDR would be vastly exceeded (Fuss et al., 2018; Hepburn et al., 2019), while engineered CDR options are not yet available at scale. Our findings align with the Land Gap

1 Buck et al. (2022) assessed the LTS of Annex I countries and came to a similar conclusion

In this report, we distinguish between two types of CDR: 1) nature-based CDR, which includes reforestation and afforestation and soil carbon sequestration; and 2) engineered CDR, which includes BECCS and DACCS

Various countries mention CCS to decarbonise their fossil-fired power plants, but we consider this a reduction measure.



*France and Italy are included in the bars for the EU and not separately shown

Figure 11

Ten G20 members' joint residual emissions by 2050 compared to their joint 2019 emissions

Report, which found that countries climate pledges, including NDCs and LTS, would require 1.2 billion hectares of land prioritised for CDR (Dooley et al., 2022). This is four times the size of India.

The G20 members apply various interpretations of what residual emissions are in their LTS. Australia and the USA, for instance, explicitly consider the costs of mitigation measures to determine residual emissions, whereas France defines "irreducible" emissions as "greenhouse gas emissions that are considered unavoidable according to *current knowledge*" (emphasis added, France, 2020, p. 163). Nine of the 17 LTS state from what sectors they expect residual emissions in the target year and all of them list agriculture and/or heavy industry as sectors that will have residual emissions by mid-century **(see → Figure 10)**. The United Kingdom, which is the only G20 member in our study to cover international bunkers in its LTS, also mentions international aviation as particularly challenging to decarbonise.

RECOMMENDATION

G20 members should define and quantify what level of residual emissions they expect by their net zero target year in future LTS submissions. This enables assessing the ambition level of countries' GHG reduction commitments and an understanding of the scale of removals required.

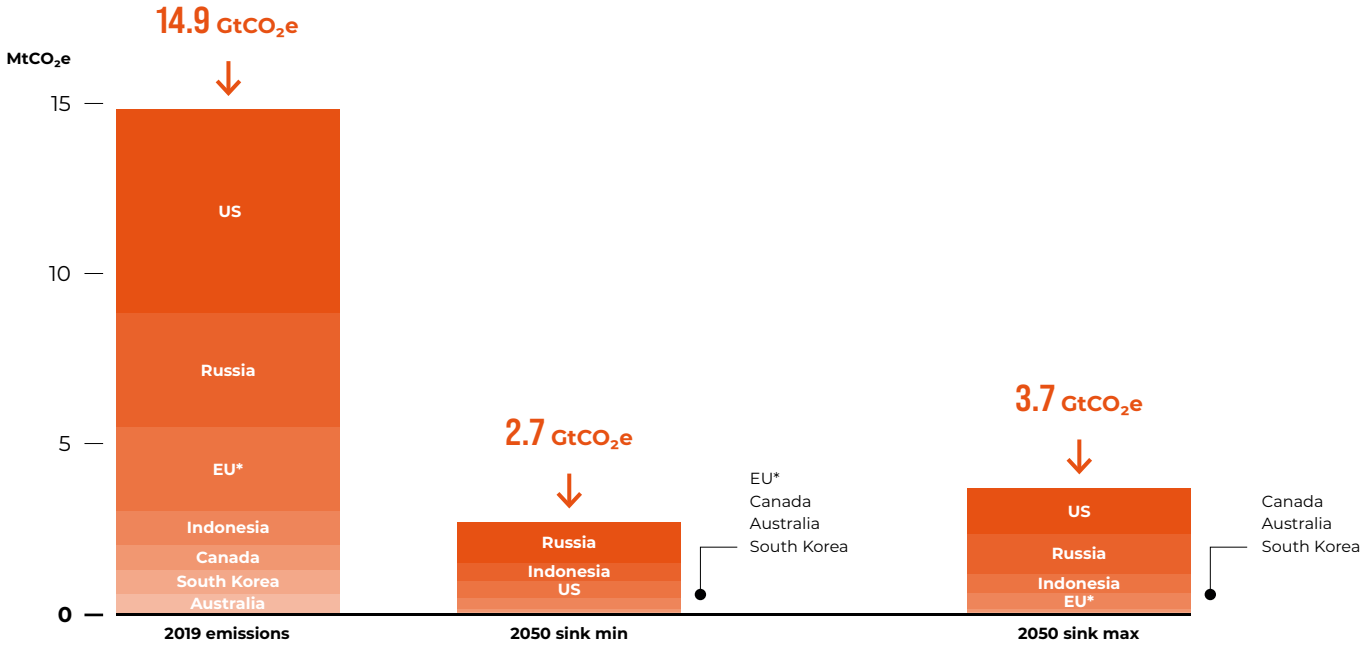
Despite the crucial role of CDR in limiting global warming, the 17 LTS provide limited quantified information, suggesting that countries may have difficulties capturing CDR in their modelling exercises. Deep emission reductions need to be coupled with CDR and storage to bring global emissions to net zero and net negative thereafter (IPCC, 2023). Five G20 members – Australia, Canada, the EU, France and the USA – provide quantified assumptions on nature-based and engineered CDR, while the UK provides quantified estimates for engineered CDR only **(see → Figure 10)**. Another four G20 members – Indonesia, Italy, Russia and South Korea – provide estimates for nature-based removals by 2050. The final seven LTS – Argentina, China, Germany, India, Japan, Mexico and South Africa - outline no assumptions on CDR at all.

We did not identify a reason for the lack of assumptions in LTS, but countries may have difficulties correctly estimating current LULUCF sinks or capturing CDR in their decarbonisation scenarios (Mace et al., 2021). To overcome these challenges, countries can share knowledge and tools to support other countries in accounting for emissions and removals in the land use sector and integrating CDR into their modelling scenarios. Robust and transparent assumptions on CDR would send a stronger signal for investments in CDR on the short and medium term (Mace et al., 2021; Smith et al., 2022) and allow for a better understanding of how realistic a given country's net zero commitment is.

Another reason for the limited quantified information on engineered CDR may be that technologies like direct air carbon capture and storage (DACCS) and BECCS are not yet mature and available at scale, and their potential for balancing out residual emissions remains uncertain. Countries should invest in the research and development of engineered CDR to better understand the potential of these measures and drive down their costs.

RECOMMENDATION

G20 members should provide transparent assumptions on nature-based and engineered CDR in future LTS. This would send a stronger signal for investing in CDR on the short and medium term, as well as allow for a better understanding of how realistic a country's net zero commitment is.



*France and Italy are included in the bars for the EU and not separately

Figure 12

Nine G20 members' joint LULUCF sink by 2050 compared to their joint 2019 emission

The G20 members that present estimates on CDR plan to remove on average 22 to 30% of their 2019 emissions, which is an overly optimistic expectation of the potential of nature-based and engineered CDR. Nine G20 members present estimates on nature-based removals around 2050 **(see → Figure 10)**. These nine plan to use nature-based CDR to remove 2.7-3.7 $GtCO_2e$ in 2050, or 20–23% of their 2019 emissions on average, predominantly through afforestation and reforestation (A/R) **(see → Figure 12)**. If all countries globally were to follow this approach, 10 to 11.4 $GtCO_2e$ would need to be removed through nature-based CDR. However, the global annual potential for nature-based CDR (i.e. A/R, soil carbon sequestration and biochar) is estimated to be just 1.7 to 7.5 $GtCO_2e$, considering environmental constraints (Fuss et al., 2018; Hepburn et al., 2019). Going beyond this global sustainable potential would have severe implications for biodiversity, water quality, and food security, amongst others.

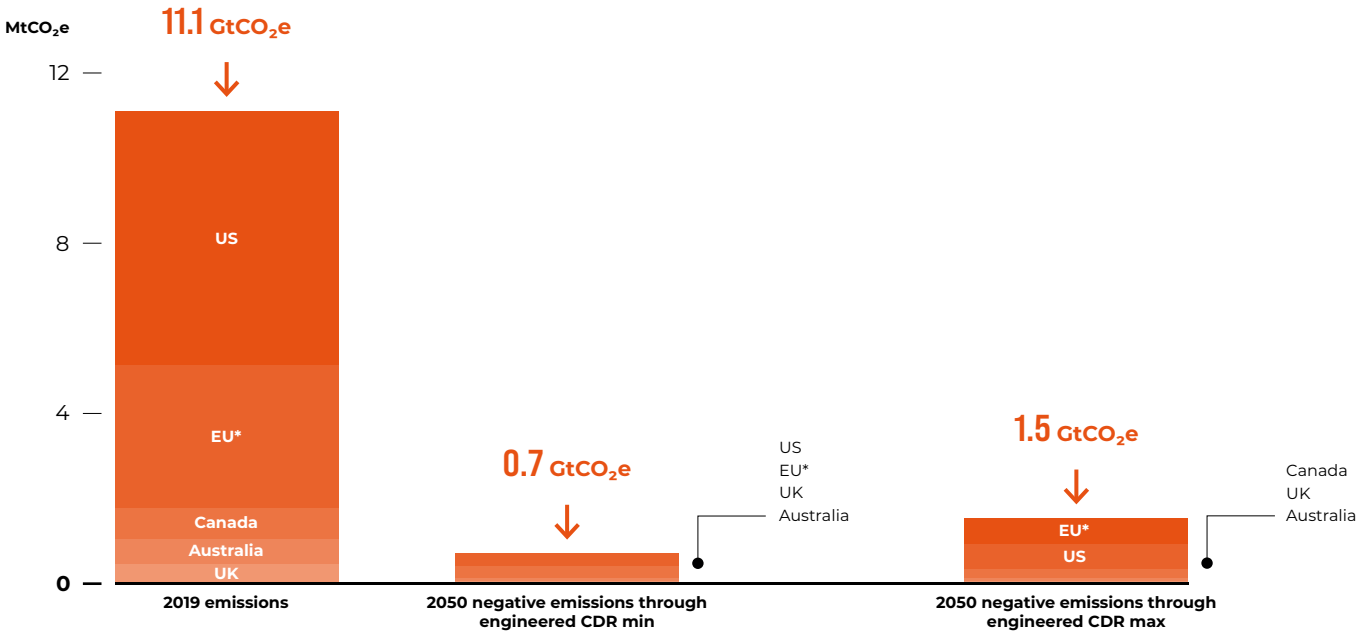
The six G20 members that outline assumptions for engineered CDR, plan to use this to neutralise 7-16% of their 2019 emissions on average **(see → Figure 10 and → Figure 13)**. They mention BECCS and DACCS as key removal measures.

There is a risk in relying on these technologies, as they are not yet proven at scale and likely to negatively impact biodiversity, food production, and human rights (IPCC, 2019; Mace et al., 2021).

RECOMMENDATION

G20 members should commit to deep emission reduction targets alongside their net zero commitments to avoid relying on CDR that may not be available due to limited geological storage capacity and lack of technological progress. Relying on uncertain CDR to compensate for residual emissions is very likely to result in overshooting the 1.5°C temperature limit.

Nine LTS see an important role for BECCS but do not discuss how to account



*France is included in the bars for the EU and not separately shown

Figure 13

Six G20 members' expected negative emissions through engineered CDR by 2050 compared to their joint 2019 emissions

for emissions from bioenergy production, transport and use across national borders. Australia, Canada, the EU, France, Indonesia, Italy, Japan, the UK and the USA foresee a role for BECCS in their LTS. While some of these countries may be able to produce the required feedstocks for bioenergy, other countries will likely have to import. This raises questions on how to best account for the emissions associated with bioenergy. Under current IPCC guidelines, countries report on emissions from harvesting biomass feedstocks in the LULUCF sector, rather than on emissions from combustion in the energy sector (Eggleston et al., 2006). This system makes it difficult to track net emissions and removals associated with bioenergy and BECCS (Mace et al., 2021). Further, the IPCC guidelines use a zero emissions factor for biomass combustion, so if coupled with CCS, countries may report negative emissions. These may be overstated if emissions from harvesting biomass are underreported. This can happen, for instance, if countries use default land-sector emission factors rather than country-specific ones (Mace et al., 2021). Although the difficulties in accounting for biomass emissions are well known, none of the nine G20 members touch upon these issues in their LTS, nor put forward proposals on how to best revise the IPCC accounting guidelines.

RECOMMENDATION

G20 members planning to use BECCS should develop robust accounting methodologies for the land use sector and guidelines for lifecycle emissions from BECCS projects. This would enable more accurate estimates of the (negative) emissions from BECCS. It would also encourage countries that import biomass for BECCS to better consider what consequences their imports have on the GHG inventory of the country where the biomass is harvested.

06 CONCLUSION

Seventeen G20 members had submitted an LTS, outlining their long-term decarbonisation and development plans, by July 2023. LTS set out long-term visions that can inform climate action and investments on the short to medium term. Collectively, LTS should chart the pathway to achieving global net zero CO_2 emissions by 2050. They can be a useful planning component to inform NDCs, sectoral mitigation and adaptation plans, and investment plans. Our assessment results in a set of recommendations for G20 members, formulated along four broad action points: Include, Specify, Enhance, and Cooperate on **(see → Recommendations)**.

Several salient topics were found to be missing in some G20 members' current LTS. We recommend the G20 members to include these topics in their future LTS submissions: international climate finance commitments, an investment plan to achieve long-term targets, adaptation targets and measures, acknowledgement of loss and damage, mitigation targets and plans for all economic sectors, targets and plans for energy efficiency, behavioural measures and the role of sustainable consumption, and transparent assumptions on nature-based and engineered CDR.

Further, we found several topics to be mentioned only vaguely and generally lacking in detail in current LTS. We recommend the G20 members to specify or provide more details on these points: finance needs for mitigation and adaptation, capacity building needs, use of international offset credits in net zero targets, type of hydrogen to be used for decarbonisation, scope and coverage of fossil fuel phase out commitments (including fossil fuel subsidies), and residual emissions levels in the net zero target year.

We also recommend the G20 members to enhance their climate ambition by committing to earlier target years for net zero emissions, committing to deep emissions reduction targets alongside their net zero targets, considering and addressing the potential negative sustainability impacts of bioenergy and BECCS, and improving the accounting methods and guidelines for BECCS.

Finally, we noted several areas that were identified as mutual priorities for G20 members or having the potential for international cooperation. We recommend the G20 members to cooperate on these topics: inclusive R&D partnerships, knowledge sharing on behavioural measures and sustainable consumption, capacity building programmes, critical minerals supply chains, hydrogen taxonomy development, phase out of fossil fuel subsidies, and developing robust accounting methodologies for land use and BECCS.

RECOMMENDATIONS

Our assessment results in a set of recommendations for G20 members, formulated along four broad action points: Include, Specify, Enhance, and Cooperate on.

INCLUDE

We recommend the G20 members to include the following in future LTS submissions:

- International climate finance commitments
- An investment plan to achieve long-term targets
- Adaptation targets and measures
- Acknowledgement of loss and damage
- Mitigation targets and plans for all economic sectors
- Targets and plans for energy efficiency
- Behavioural measures and the role of sustainable consumption
- Transparent assumptions on nature-based and engineered CDR

SPECIFY

We recommend the G20 members to be more specific on the following topics that are only vaguely addressed in current LTS:

- Finance needs for mitigation and adaptation
- Capacity building needs
- Use of international offset credits in net zero targets
- Type of hydrogen to be used for decarbonisation
- Scope and coverage of fossil fuel phase out commitments (including fossil fuel subsidies)
- Residual emissions levels in the net zero target year

ENHANCE

We recommend the G20 members to enhance their climate ambition by:

- Committing to earlier target years for net zero emissions
- Committing to deep emissions reduction targets alongside their net zero targets
- Considering and addressing the potential negative sustainability and climate impacts of bioenergy and BECCS
- Improving the accounting methods and guidelines for BECCS

COOPERATE ON

We recommend the G20 members to cooperate internationally on the following topics:

- Inclusive R&D partnerships
- Knowledge sharing on behavioural measures and sustainable consumption
- Capacity building programmes
- Critical minerals supply chains
- Hydrogen taxonomy development
- Phase out of fossil fuel subsidies
- Co-development of robust accounting methodologies for land use and BECCS

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ANNEX 1: QUESTIONNAIRE

CONTEXTUAL INFORMATION

Indicator

Population, total (million people)
GDP (constant 2015 US$)
GDP per capita (constant 2015 US$)
Total greenhouse gas emissions ($MtCO_2e$)
Population, total (same year as total GHG emissions) (million people)
Emissions per capita (tCO_2 per capita)
Urban population (% of total population)
Manufacturing, value added (% of GDP)
Electricity production from coal sources (% of total)
Renewable energy consumption (% of total final energy consumption)
Emissions peak: How many years are between the (expected) emissions peak year and net zero?
When was the LTS submitted?

GENERAL INFORMATION

Economic and development goals

What are the economic and development goals outlined in the LTS?

International cooperation

Does the LTS state that the country needs / is interested in / generally commits to international cooperation to achieve its climate targets?

Equity

Does the LTS state whether the country considers the LTS a fair and equitable contribution to global efforts of limiting global warming?
[If yes] does the LTS explain why the country considers its LTS a fair contribution?

ADAPTATION AND RESILIENCE

Targets

Does the LTS outline targets for adaptation and resilience?
[If yes] What are the targets for adaptation and resisilience?

Adaptation

Does the LTS identify climate impacts for the respective country?
What are some of the identified climate impacts?
What are some of the identified adaptation measures in the LTS?
Does the LTS identify the need for adaptation finance?
Does the LTS identify sectoral adaptation needs?

Loss and damage

Does the LTS highlight loss and damage?

MITIGATION TARGETS

Headline target

What is the headline target?
Does the headline target depend on reductions or removals from outside the country's own borders?
What is the headline target year?

Net zero

Does the country commit to net-zero emissions? (This includes similar terminologies, such as carbon neutral and climate neutral.)
By what year does the country commit to net-zero emissions?
Is the net-zero target a domestic target?
[For Global South] By what year does the country commit to peak its GHG emissions?
[For Global North] In what year did GHG emissions peak?

Target coverage (headline target)

Does the target encompass all emissions, incl. LULUCF and agriculture?
Does the target cover international aviation and shipping?

Sectoral targets

Does the LTS outline sectoral targets and plans?
[If yes] What are the sectoral targets?
Does the LTS state what sectors will be most difficult to decarbonise?
[If yes] What sectors will be most difficult to decarbonise?

Does the LTS provide plans for the power/energy sector?
Does the LTS provide plans for the industry sector?
Does the LTS provide plans for the transport sector?
Does the LTS provide plans for the buildings sector?
Does the LTS provide plans for the agriculture, fisheries and forestry sector?
Does the LTS provide plans for the waste sector?
Does the LTS provide plans for another sector?
Lifestyle emissions and consumption patterns
Does the LTS refer to lifestyle emissions and consumption patterns?

NDC & Interim Targets

Does the LTS include milestones and interim targets
Does the LTS refer to the NDC and explain whether the two are aligned?

ENERGY & ENERGY EFFICIENCY

Energy efficiency

Does the LTS outline energy efficiency targets and plans?

Renewables

Does the LTS include targets for renewable energy capacity and generation?
What are these targets?
Does the LTS outline a strategy to achieve the renewable energy targets? (e.g., information on infrastructure rollout)
Does the LTS outline what sectors are priority sectors for renewable energy consumption?
Does the LTS provide plans for storage of renewable energy?

Hydrogen

Does the LTS rely on hydrogen?
Does the country plan to import or export hydrogen?
Does this ambition address sustainability and energy access issues?
Does the LTS outline what sectors are priority sectors for hydrogen consumption?

Bioenergy

Does the LTS rely on bioenergy?

Nuclear

Does the LTS rely on nuclear?

FOSSIL FUEL PHASE OUT

Coal commitments

Does the LTS include a commitment to phase out coal?
If there is such commitment, does it apply to existing coal fields within the country's own territory?
If there is such commitment, does it cover active exploration only or also importing and financing coal exploitation?
By what year does the country commit to phase out coal?

Oil commitments

Does the LTS include a commitment to phase out oil?
If there is such commitment, does it apply to existing oil fields within the country's own territory?
If there is such commitment, does it cover active exploration only or also importing and financing oil exploitation?
By what year does the country commit to phase out oil?

Gas commitments

Does the LTS include a commitment to phase out gas?
If there is such commitment, does it apply to existing gas fields within the country's own territory?
If there is such commitment, does it cover active exploration only or also importing and financing gas exploitation?
By what year does the country commit to phase out gas?

Fossil fuel subsidies

Does the LTS address the phase out of fossil fuel subsidies?

Just energy transition

Does the LTS describe how the country will ensure a just energy transition?

CDR & LULUCF

Residual emissions

Does the LTS include a definition of "residual emissions"?
Does the LTS state what level of residual emissions are expected by the target year?
What sectors will have residual emissions by the target year?

CDR assumptions

On what type of removals does the LTS rely on to reach net zero?
Does the LTS outline what assumptions for removals were made?
Does the LTS address CDR limitations such as scarcity and reversibility?

FINANCE, TRADE, CAPACITY BUILDING & TECHNOLOGY TRANSFER

Finance

What are the investment needs that the LTS explicitly states?
From what sources does the country seek climate finance?
Does the LTS address the creation of new instruments to leverage public finance?
[if yes] What are these new instruments?
Does the LTS address the need to leverage private sources of finance to increase climate finance flows?

International finance

Does the LTS provide whether the country needs international climate finance or plans to provide such finance to other countries?
How much is needed?
How much is provided?

Technology transfer

Does the LTS address R&D and technology transfers relevant to the transformation to net zero?

Capacity building

Does the LTS address the need for capacity building?
What capacity-building measures does the LTS refer to?

Trade policies favouring low-carbon products and services

Does the LTS address the role of trade policies in the transformation to net zero?

GOVERNANCE OF THE LTS

Legal status of the net zero target

What is the legal status of the net-zero target (or other long-term reduction target) outlined in the LTS?

Review of the LTS

Does the LTS outline if the country will (regularly) revise and update the LTS?

Analysis and modelling

Is the LTS informed by analysis and modelling excercises?

Role of science and experts

Does the LTS process involve scientists and experts?

Inter-ministerial coordination

Does the LTS process involve inter-ministerial coordination?
What is the set-up of inter-ministerial coordination?

Stakeholder engagement

Does the LTS process include public and private stakeholder engagement at all stages?
Were all categories of relevant stakeholders involved?

ANNEX 2: ASSUMPTIONS ON RESIDUAL EMISSIONS AND CDR

G20 member	Residual emissions in 2050 ($MtCO_2e$)		LULUCF sink in net zero target year ($MtCO_2e$)		Engineered CDR in net zero target year ($MtCO_2e$)		Source
	min	max	min	max	min	max	
Argentina	No data identified						
Australia	215	215	27	27	38	38	Australia (2021, p. 59, scenario "The Plan")
Brazil	No LTS						
Canada	100	301	100	100	0	201	Canada (2022, p. 34)
China	No data identified						
EU	23	26	317	472	281	606	European Commission (2018, pp. 196, 198)
France	82	82	66	66	16	16	France (2020, p. 18)
Germany	No data identified						
India	No data identified						
Indonesia	820	820	550	550	No data identified		Indonesia (2021, p. 34, LCCP scenario)
Italy	65	85	65	85	No data identified		Italy (2021, p. 19)
Japan	No data identified						
Mexico	313	313	313	313	No data identified		Mexico (2016, p. 73)
Russia	630	630	1200	1200	No data identified		Russia (2022, p. 34)
Saudi Arabia	No LTS						
South Africa	No data identified						
South Korea	No data identified		15	15	No data identified		Republic of Korea (2020, p. 99
Tukrey	No LTS						
UK	75	81	No data identified		75	81	UK (2021, pp. 72–73)
USA	790	1950	500	1350	300	600	USA (2021, p. 45,48)

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