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Nationally determined contributions-enhanced climate mitigation actions and safeguards (ECMAS) indicator framework for helping countries design sustainable and inclusive net-zero emissions reduction outcomes

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Abstract

Global warming is unequivocal. The Paris Agreement requires that countries undertake a global stocktake beginning in 2023 at the 28th Conference of Parties to be held in Doha and every five years thereafter. Countries will demonstrate aggregate progression towards balancing greenhouse gases by sources and removals, adapting to the threats from climate change, the flow of climate finances, and contribution to the achievement of sustainable development goals. This paper designs an Enhanced Climate Mitigation Actions and Safeguard (ECMAS) Indicator Framework and applies it to 188 Nationally Determined Contributions (NDCs). It assesses the implications of the quality of the information provided to improve clarity, transparency, and understanding of the NDCs. Findings show inconsistencies in terms used to describe emission reduction (ER) targets, unmet mitigation ambitions, and poorly elaborated safeguards. The study concludes that the information in the NDCs may jeopardize the sustainability and inclusiveness of net-zero ER targets and Paris Agreement goals, and the ECMAS Indicator Framework can help countries design and pursue appropriate pathways. Our findings recommend the need for policy guidelines to harmonize terminologies in NDCs, promotion of tools for enhancing net-zero ER targets and strengthening of



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institutional arrangements for elaborating and ensuring safeguards against socio-ecological inequalities are promoted and respected.

Keywords: Net-zero emission reduction targets, power dynamics, marginalized, socio-ecological inequalities, safeguards, sustainable and inclusive development

INTRODUCTION

The unprecedented increase in global average temperatures has adversely altered the climate system. The resulting global warming, driven by the historical accumulation of greenhouse gas (GHG) emissions, poses significant risks to the survival and well-being of people, ecosystems, and the planet. In response, the global climate regime has called upon State and Non-State Actors to address (GHG) emissions to and from the global atmosphere^[1-4]. Countries have responded to the call by preparing national climate mitigation plans, referred to as Nationally Determined Contributions (NDCs), which they communicate to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat (see Section "Nationally determined contributions"). Among the main GHG mitigation activities featured in almost all NDCs are decarbonizing technologies and ecosystem-based solutions aimed at avoiding, reducing, and removing GHG emissions or specific GHGs from the global atmosphere^[5,6]. Although ecosystems play a direct role in reducing and avoiding GHG emissions by acting as sinks and preventing their destruction, they also complement decarbonization technologies by removing any residual emissions. In addition to these climate mitigation functions, ecosystems are critical in sustaining marginalized sectors, places, ecosystems, and social groups^[7-9]. The Intergovernmental Panel on Climate Change (IPCC) has also cautioned that the absorptive capacity of ecosystems for the ever-increasing GHG emissions is near exhaustion^[10,11].

Yet, despite the concept of ecosystem-based solutions being on the international climate change negotiations agenda for about 30 years, concerns and debates about the prevalent socio-ecological inequalities in global climate governance have persisted in scholarly work, policy discourses, and the politics of development^[12-15]. The literature argues about the limitedness of information provided in successive NDCs in improving the clarity, transparency, and understanding on terminologies, net-zero ER targets, and safeguards for protecting the well-being of the marginalized^[16-20]. These limitations are likely to jeopardize global efforts in achieving Paris Agreement goals by mid-century within the context of sustainable and inclusive development (SID). These goals include undertaking mitigation efforts to hold the global average temperature increases below 2 °C, pursuing further efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, strengthening adaptation and climate resilience, ensuring adequate financial flows, and contributing to the achievement of sustainable development goals of 2030. This paper examines the knowledge gaps that may contribute to countries' inability to achieve the Paris Agreement goals within the context of sustainable and inclusive development outcomes.

Knowledge gaps

Currently, there are three relevant knowledge gaps. First, the discourse on net-zero GHG emissions reduction is still nascent. The aggregate synthesis report of NDCs for 2016^[5] and 2022^[6] shows that, although countries are required to collectively contribute to achieving the Paris Agreement goals, the successive NDCs are burdened with inconsistencies in the terminologies used in framing net-zero emissions reduction targets, ecosystem-based solutions, and safeguards. Regarding the net-zero ER target, various terminologies with different implications have been used to frame the concept of balancing GHGs emissions from sources and removals. This also includes timelines and periods, GHGs coverage, scope of sectors, categories, and pools. Inconsistencies exist across institutions, NDCs, sectors, and categories (see Section "The concept of net-zero emissions reduction targets").

Concerning climate mitigation actions, inconsistencies exist across countries and institutions arrangements in framing mitigation planning process, interventions, and assumptions and methodology approaches. Although the IPCC has grouped the sectors responsible for GHG emissions to include energy, industrial processes, and product use (IPPU), agriculture, forestry, and other land use (AFOLU), and waste^[21], the NDCs frame the sectors in varied ways depending on each country's national circumstances and priority mitigation options^[5,6]. The Paris Agreement and successive decisions have used general terms such as sinks to refer to clusters of sectors, including agriculture, forests, and oceans^[1,2]. These terms may refer to specific terms such as low-carbon agriculture, improving crop and livestock production, afforestation, reforestation, revegetation, wetland restoration, Reduced Emissions from Deforestation and forest Degradation (REDD), and tourism^[5,6]. The UNFCCC also mentions decarbonization technologies, which are then broken down into specific energy solutions such as renewable energy, clean energy, energy efficiency, sustainable transport, and waste management. The FAO^[22] uses terms aligned with its global mandate on food systems, including agriculture, crops and crop production, livestock and grassland, fisheries and aquaculture, and land use and land-use sectors. Concerning mitigation co-benefits from adaptation, the UNFCCC^[6] has detailed specific climate mitigation actions^[6] to include agriculture, livestock and pastoralism, fisheries, freshwater, biodiversity, ecosystem, and forests. However, the NDCs framings include broad categories, such as decarbonization technologies that could be applied in the energy and waste sectors, ecosystem-based solutions that could be applied in the AFOLU sector, and mitigation co-benefits from adaptation and economic diversification, which could be applied to a mix of several interventions across different sectors including energy, IPPU, AFOLU, and waste sectors^[1,2]. The UNFCCC uses some general terms, such as land- and ecosystem-based solutions^[14,23-26].

Second, although the Paris Agreement has provided some safeguards to ensure its goals are achieved under context of sustainable and inclusive development, the rules, guidelines, and procedures for tackling potential socio-ecological inequalities are poorly framed^[1]. Some of these terms and concepts include the principles of equity, sustainability, eradication of poverty, food security, ending hunger, decent work, quality of job, obligations of human rights, right to health, gender equality, empowerment of women, inter-generational equity, climate justice, and climate empowerment actions such as education, training, public awareness, public participation, public access to information, and cooperation at all levels. The lack of elaboration of safeguards is also reflected in the successive NDCs submitted to the UNFCCC secretariat^[5,6]. Notably, such gaps in clarity, transparency, and understanding of safeguards might jeopardize the protection and well-being of marginalized sectors, places, ecosystems, and social groups. The gaps may also encourage corruption in climate finances both by recipient countries and private sectors' claims for ER offsets and credits (see Section "THEORETICAL FRAMEWORK").

Notably, the Paris Agreement^[27-33] call on non-state actors to widen and deepen emissions reduction (ER) across the country's entire economy has attracted high GHG emitters, including state and private enterprises, financial institutions, regions, and cities. These actors differ in their understanding, approaches, and interests, which may lead to inconsistencies in the framing of key concepts and terms in their ER transition plans and country NDC. In the absence of clear, transparent, and understood safeguard rules, guidelines, and procedures, the rich tend to favor economic gains at the cost of socio-ecological inequalities, which adversely affects the poor and marginalized^[34-36]. This is witnessed in many ecosystem-based solutions which in the absence of safeguards, the power dynamics between the rich and poor might lead to evictions of local communities and indigenous peoples from their ancestral land and exclusion from accessing ecosystem services^[27,28,30,31,34-37].

Third, although the global stocktake is fast approaching at the end of 2023, the tools for helping countries to assess and report their progression towards achieving the Paris Agreement goals and net-zero ER targets are poorly designed^[22,38-40]. A review of some of the accessible tools from the literature shows that most tools are designed and applied to respond to organizational interests^[5,6,40-44]. In 2016^[5] and 2022^[6], the UNFCCC used different analytical approaches to assess countries' progression towards achieving the Paris Agreement goals. Notably, although the UNFCCC aggregate analysis made efforts to examine information on clarity, transparency, and understanding for the different aspect of NDC, it failed to organize and link the components, elements, and indicators for net-zero ER targets, climate mitigation actions, and safeguards in a manner that could compare aggregate progress across the successive NDCs towards achieving the Paris Agreement goals. Such approaches obscure knowledge gaps in inconsistencies in terminologies, deficits in ambitions and power dynamics between the rich and poor. This, in turn, undermines the opportunity for countries to learn feasible design considerations for sustainable and inclusive net-zero ER pathways^[6]. The World Resources Institute^[38] has proposed a methodology for assessing countries' progression in enhancing their GHG emissions across successive NDCs. The report suggests that inconsistencies in the projected net-zero ER targets and timelines across the NDCs can be addressed by extrapolating emissions levels from the most recent previous estimates to a harmonized projected level, including key years such as 2025, 2030, and 2050. However, there are no efforts to address inconsistencies in terminologies and deficits in ambitions, establish linkages across targets, actions and policy measures, while there is no reference to safeguards.

The United Nations Development Programme^[45] has proposed the use a "ladder of ambition" to assess the overall snapshot of momentum concerning the direction of overall climate ambition in a country's NDC. The tool separately examines a country's mitigation ambition and adaptation. A country's ambition is determined using three quality dimensions, framed as ownership, feasibility, and robustness, which is scored using four performance levels that include enhanced, updated, unclear, and no plan for mitigation or adaptation ambition. However, the assessment has a weak linkage between ambitions for net-zero ER targets, climate actions, and safeguards, making it difficult to derive sustainability and inclusiveness of net-zero ER pathways. The WWF^[39] has proposed a checklist for setting a clear and constructive benchmark for assessing countries' incremental progress in their NDCs ambitions towards the Paris Agreement temperature goal of 1.5 °C. The checklist examines five benchmarks of preference: ambition, fostering systemic change, inclusiveness and participation, contribution to sustainable development, and tracking progress. The checklist assigns each NDC an overall rating that includes "the NDC we want", "a short way to go", "some way to go", and "NDC we do not want". However, the checklist fails to link the benchmarks with potential sustainable and inclusive low-emissions, climate-resilient, and adaptation development pathways. The African Development Bank^[40] has developed an NDC advance platform to assist its member countries in identifying climate adaptation initiatives of mutual investment interests. Countries then develop climate investment plans, apply for financing, and develop monitoring and reporting mechanisms to implement priority projects effectively. The report argues that the platform can help to facilitate regional shifts towards a low-emissions and climate-resilient pathway aligned to the Paris Agreement and the Sustainable Development goals, and the Sendai Framework for Disaster Risk Reduction. However, the platform design considerations do not demonstrate which aspects are assessed and how the results are translated into sustainable and inclusive net-zero ER and climate-resilient pathways.

Hence, this paper aims to address the question: How can new and innovative tools be developed to help countries assess their progression to achieve the Paris Agreement goals and net-zero ER targets under the context of sustainable and inclusive development outcomes? This question is further broken down into the following sub-questions: (i) What are the aggregate global trends and patterns concerning (a) the communication of the NDCs to the UNFCCC secretariat and (b) the quality of the information provided to

improve the clarity, transparency, and understanding of NDCs concerning net-zero ER targets, climate mitigation actions, and safeguards against potential socio-ecological inequalities? and (ii) How can countries improve their NDC to pursue sustainable and inclusive net-zero ER and climate-resilient pathways?

This paper addresses these questions through six analytical steps. First, we review the concept of sustainable and inclusive development to draw insights on some of the relevant principles for elaborating safeguards to tackle potential socio-ecological inequalities under the NDC (see Section "THEORETICAL FRAMEWORK"). Second, we examine scholarly and policy literature to gain insights into the long-term global temperature goal and net-zero targets see Section "The concept of net-zero ER targets"), ecosystem-based solutions (see Section "The concept of Climate mitigation actions"), and socio-ecological inequalities (see Section "THEORETICAL FRAMEWORK"). Third, we develop a methodological approach to build an assessment framework (see Section "BUILDING THE ECMAS INDICATOR FRAMEWORK"). The framework helps countries to analyze the quality of the information provided in the NDCs to improve the clarity, transparency, and understanding of net-zero ER targets, climate mitigation actions, and safeguards. Fourth, we apply the ECMAS Indicator Framework to 188 successive NDCs for 2016 and 2022 to examine the quality of the information provided for improving clarity, transparency, and understanding of net-zero ER targets, climate mitigation actions, and safeguards. Fifth, we build feasible sustainable and inclusive net-zero ER pathways based on most clear, transparent, and understandable information on net-zero ER targets, climate mitigation actions, and safeguards. Six we draw conclusions and recommendations on the implications of the results from the ECMAS Indicator Framework on how countries can assess their aggregate global progression towards achieving the Paris Agreement goals and any necessary improvement needed in preparing, implementing and monitoring their NDCs.

The concept of net-zero emissions reduction targets

The IPCC and the Paris Agreement of 2016 set long-term global temperature goal to be achieved in the second half of the century^[1,46]. The goal has been reaffirmed by subsequent CoP decisions, including CoP 26 Glasgow Climate Pact and CoP 27 in Sharma El Sheik^[2-4]. Noting the enormous task in achieving the goal, the UNFCCC has called on states and non-state actors to participate and collectively enhance their ambitions to limit increase in global average temperature to 1.5 °C above pre-industrial levels. The aim is to ensure the safety and well-being of the planet, including people, nature, ecosystems, and the climate system.

The IPCC and the UNFCCC framed the concept of balancing anthropogenic emissions by sources and removals in very general terms, opening floodgates to interpretations and inconsistent framing of the concept by the multiple actors engaged in climate governance. Consequently, there exist numerous inconsistencies in framing of terminologies on targets, measures and safeguards among the different actors. The IPCC has provided two scenarios for limiting global average temperature. The first scenario requires undertaking enhanced economy-wide measures to achieve 2 °C by mid-century. The second scenario requires undertaking the highest possible and unprecedented ambitious economy-wide across all sectors, deep into the various activities, far-reaching across the value-chain, and near-term ER measures. It also requires employing innovative carbon dioxide removal (CDR) technologies; and fostering societal changes to low-emission consumption lifestyles so as to achieve rapid peaking and further undertake rapid ER so as to achieve a global average temperature of 1.5 °C^[21,46-48] by the second half of the century. Based on this, the IPCC in its reports on climate science, impacts, adaptation and vulnerabilities, and mitigation, has framed the targets and measures for the balancing of carbon dioxide emissions by sources and removals by sinks and technologies to achieve net-zero emissions^[49-58]. The UNFCCC, major international organization, and governments have interpreted and framed the concept using terminologies that aligns with their mandate and the common parlance of their target actors. This has led to divergent framings of net-zero emissions

targets. Yet, the private sector have framed the concept in ways that appeal to the global climate change regimes, governments and clients so as to remain relevant in the market. The result is a proliferation of terms that differ not only in terms of semantics but also in their implications on NDC elements, targets, measures, and safeguards, including reference points, targets, metrics, timelines, GHG scopes, categories, and principles. Currently, different framing of net-zero emission exist across different institutional arrangements for governing climate change with respect to^[59-61], food systems^[62,63], and forestry^[64,65] sectors. Considering the principles of respect for sovereignty, non-intrusiveness, and Common but Differentiated Responsibilities and Respective Capabilities (CDRRC), and the lack of an international mechanism for enforcing compliance to global climate policies, these inconsistencies have persisted since the adoption of the Paris Agreement and might continue undeterred. In recognizing the daunting task of attempting to harmonize these terminologies, the paper aims at commencing scholarly and policy discourses to improve the quality of information provided for clarity, transparency, and understanding of NDCs.

Figure 1 presents a graphical superimposition of terms and concepts related to the scenarios and pathways towards achieving Paris Agreement goals. There is evidently noticeable high-density of overlaps and inconsistencies in the terms and concepts informing the preparation, implementation, and monitoring of NDCs.

Table 1 shows some of the terms and concepts drawn from scholarly and policy literature to interpret the Paris Agreement goals and net-zero ER targets^[47,48]. Notably, the IPCC and the UNFCCC have defined only three terms: net-zero emission reductions, climate neutrality, and carbon neutrality^[49], while the rest have emerged from the private sector, financial institutions, and development agencies. Some terms, such as "1.5 °C aligned" refer to the highest ambitious efforts to limit global average temperature relative to pre-industrial levels. Other terms, such as GHG reductions, GHG removals, neutralization, compensation, decarbonization, offsetting, and insetting, refer to the process of balancing emissions from sources and removals from sinks and decarbonizing technologies. Still, other terms, such as net-zero ER, absolute net-zero, climate neutrality, GHG neutrality, carbon neutrality, and carbon negative, refer to the outcome from balancing ER by sources and removals by sinks and decarbonization technologies^[50-52]. Other terms refer to all the GHGs, while some are more specific apply to carbon dioxide emissions. In addition, some terms refer to either net-zero with or without residual emissions, while others go beyond to focus more on carbon dioxide removals through both sinks and decarbonization technologies. Yet, some terms refer to temperature with details on either stabilizing or lowering below certain reference points, others refer to GHGs, and still, others refer to the outcome of the climate system following successful implementation of climate mitigation actions. Some terms specify "ER conditionalities" which requires that GHG reductions or removals be additional, like-for-like, transparently estimated, exclusively claimed, actual while avoiding under or overestimation, and comparable in global warming impacts while employing durable carbon capture and storage technologies. Some terms have specified reference points, timelines, and mechanisms for GHG ER while others have not.

The UNFCCC in anticipation of these inconsistencies, provided guidance that countries, while communicating their NDCs, should provide adequate information to improve clarity, transparency, and understanding of their plans. The Glasgow Climate Pact has elaborated that countries need to pursue ER measures that can limit the increase in global average temperature to 1.5 °C above pre-industrial level thereby ensuring the safety of the planet. This involves the highest ambitions possible economy-wide and near-term mitigation efforts to allow urgent global peaking of GHGs by 2025^[5], furthering ER by 45 percent by 2030 relative to 2019 emissions levels^[50,53], achieving net-zero ER by mid-century^[1,21], net-zero ER for all GHGs by 2060, and "Climate Neutrality" by the end of the century^[6,21]. Achieving climate neutrality means

Table 1. Terms derived from the concept of balancing GHG emissions by sources and removal by sinks

Terms	Definitions	Common usage
Paris aligned	Mitigation targets deemed feasible to achieve the Paris Agreement goal of limiting global average temperature to 2 °C and further to 1.5 °C above pre-industrial levels	Development Bank
1.5 °C aligned	Achieve through GHG emissions mitigation scenarios whose long-term goal is to limit the increase in global average temperature to 1.5 °C above pre-industrial levels	Private sector
GHG reductions	Achieved through mitigation actions that reduced specific quantities of GHG emissions based on reference targets/points and timelines. This may include replacing or avoiding fossil energy with renewable energy, reducing consumption of emissions-intensive products and inputs, and avoiding the destruction of ecological carbon sinks	IPCC
GHG removals	Achieved through mitigation action that removes GHG from the global atmosphere relative to reference targets, points, and timelines. May include ecosystem-based mitigation activities, e.g., afforestation, reforestation, enhancing soil carbon, bioenergy with carbon capture and storage	IPCC
Neutralization	A state where an actor removes residue GHG emissions through offsetting and other mitigation activities outside its value chain. Only required if residual emission remains after achieving net-zero status. It may involve <i>technological removals</i> , e.g., direct air capture with geological storage and <i>ecosystem-based solutions</i> , e.g., reforestation	Actor
Compensation	Process, where an actor reduces or removes GHG emissions through offset and mitigation co-benefits from activities outside its value chain. Requires additionality, exclusive claim, and no overestimation	Actor Intermediary to net-zero
Decarbonization	Process reducing CO ₂ and other GHG emissions from a product, actor, or country	Product, Actor
Offsetting	Process of reducing, avoiding, or removing GHG emissions through external activities to an actor to compensate for own emissions	Actor
Insetting	Process of reducing or removing GHG emissions from actor’s scope 1: direct emissions sources such as processes; scope 2: indirect energy sources such as purchased energy; and scope 3: indirect emissions sources such as assets, purchased goods, transport, etc	Private sector
Net-zero	Achieved when anthropogenic GHG emissions are balanced with removals over a specified period based on science-based pathways.	IPCC
Net-zero emissions reduction	Achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period. Any remaining emissions are re-absorbed from the atmosphere by oceans and forests, for instance	IPCC
Negative emissions	Removal of GHGs from the atmosphere by deliberate human activities in addition to the removal that would occur via natural carbon cycle processes	Private sector
Net negative emissions	Achieved when more greenhouse gases from human activities are removed from the atmosphere than are emitted into it	Private sector
Net-zero carbon dioxide	Achieved when anthropogenic CO ₂ emissions are balanced globally by anthropogenic CO ₂ removals over a specified period. Any remaining emissions are offset	Private sector
Absolute net-zero	Achieved when no GHG emissions are attributable to an actor’s activities across all scopes.	Actor End-state
Climate neutrality	A state where human activities have no net effect on the climate system. Achieved by balancing residual emissions with emission (carbon dioxide) removal. In addition, accounting for regional or local biogeophysical effects from human activities that may affect surface albedo or local climate	IPCC
Climate positive	Achieved when actors the GHG emission removals from internal and external sources exceed its emissions	Private sector
GHG neutrality	Actor’ net GHG emissions contribution to the global atmosphere is zero. Achieved when all the GHG emissions attributed to an actor are fully offset regardless of reference targets and timeline	Actor Intermediate to net-zero
Carbon Neutrality	A state where an actor fully compensates and exclusively claims CO ₂ emission reductions or removals over a specified period. Achieved when an actor’s net CO ₂ emissions contribution to the global atmosphere is zero. Only carbon dioxide emissions	IPCC Intermediary to net-zero
Carbon negative	Achieved when actors’ CO ₂ emissions removals from internal and external sources exceed their emissions	Private sector

Sources ^[1,6,41,47,58,59].

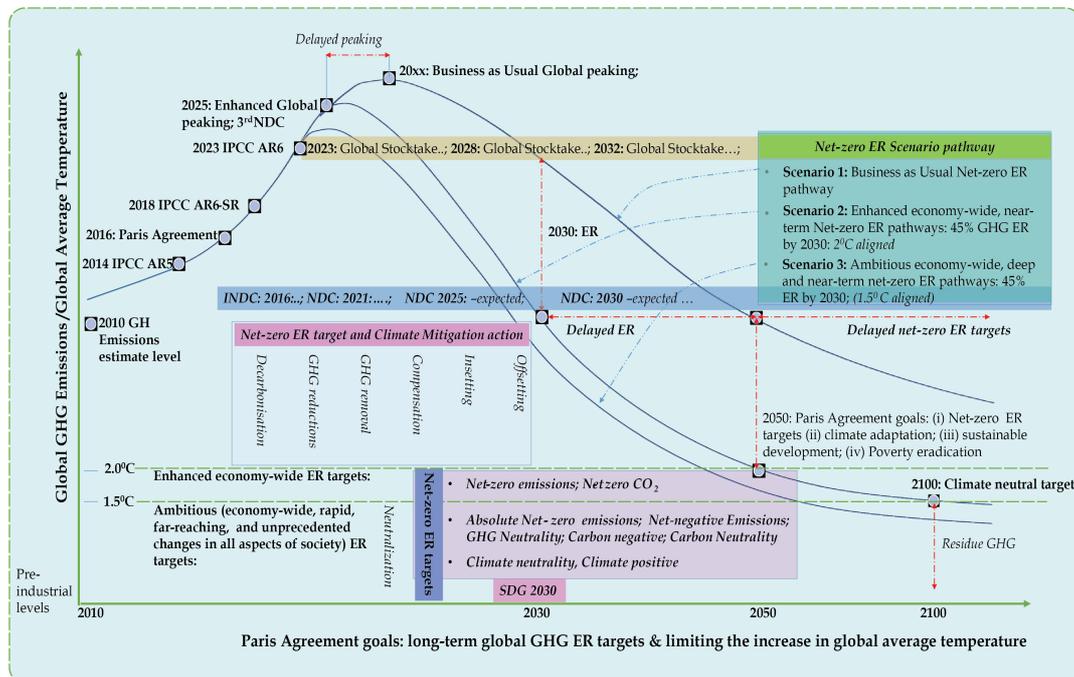


Figure 1. Long-term global average temperature goal and net-zero ER targets and pathways. Sources: IPCC^[10,11] and UNFCCC^[14,23-26].

that countries need to remove 100 Gigatons of GHGs ER and further 1,000 metric Gigatons of CO₂ before 2100^[54]. The UNFCCC recognizes that wealthy and industrialized countries have historically contributed more GHG emissions than developing countries (DCs)^[55,56]. In addition, these rich countries have more capacity in terms of competencies, finances, technical skills, and technology to undertake more ambitious and faster mitigation measures than DCs. Thus, DCs will require more time to achieve net-zero ER targets; hence, they need support from developed countries to undertake the highest possible ambitious ER and build their adaptive capacity^[57].

Nationally determined contributions

The Paris Agreement further requested countries to prepare and submit their Nationally Determined Contributions (NDCs) starting in 2020 and every five years thereafter. The NDCs are non-legally binding pledges and commitments by all countries to clearly and transparently disclose their GHG ER targets under business-as-usual and enhanced ER scenarios, measures for achieving the ER and adaptation, means of implementation, and summary of information to facilitate clarity, transparency, and understanding of the NDCs^[1,66-68].

The UNFCCC has requested countries to progressively enhance their NDC by revising subsequent communications at any time to demonstrate the highest possible level of ambitions. Moreover, the NDC process is expected to inform the periodic global stocktake, beginning in 2023 and every five years thereafter^[1,69]. The Paris Agreement has outlined six areas to demonstrate enhanced ambitious efforts towards achieving net-zero ER targets. These areas include emission reduction targets, mitigation actions, capacity for adaptation and climate-resilience, technology development and transfer, action for climate empowerment, and enhanced transparency^[1]. The first enhanced ambitious effort pertains to progression towards balancing GHG emissions by sources and removals through incremental targets that cumulatively help achieve absolute global net-zero emissions by mid-century. Countries agreed to urgently achieve global peaking and undertake rapid reductions thereafter according to best available science so as to balance

“human-caused” emissions by sources and removals by sinks of GHGs in the second half of the century. Countries committed to achieve these ER targets guided safeguards of equity, context of sustainable development, and efforts to eradicate poverty. The second enhanced ambitious effort pertains to the global goal of adaptation. Countries need to enhance adaptive capacity, strengthen resilience, and reduce vulnerability to climate change. The aim is to protect communities and social groups, livelihoods, and ecosystems to reduce their vulnerability to the adverse effects of climate change. Adaptation actions need to be guided by science and appropriate traditional knowledge, knowledge of indigenous peoples, and local knowledge systems. In addition, it needs to be integrated into relevant socio-economic and environmental policies and actions. Enhanced ambitious efforts are needed to strengthen institutional arrangements and partnerships to mobilize finances flow from domestic sources and international cooperation. This support is important in facilitating systematic observation of the climate system, scientific research, and sharing of information. The third enhanced ambitious effort is on the provision of financial resources to assist DCs in mitigation and adaptation. This can be achieved by mobilizing new, innovative, and scaled-up climate finance from various sources, instruments, and channels. The fourth enhanced ambitious effort is on the long-term vision of fully realizing technology development and transfer to improve resilience and reducing GHG emissions. Countries need to elaborate on how they intend to accelerate, encourage, and enable innovation at different stages of the technology cycle. The fifth enhanced ambitious effort is on building the capacity and ability of least developed countries to implement adaptation and mitigation actions, including technology development and transfer, access to climate finance, building of capacity. Notably, capacity building needs to focus on education, training, public awareness, access to accurate information in a timely and transparent manner. The sixth enhanced ambitious effort is on the establishment of an Enhanced Transparency Framework (ETF). Countries need to elaborate their commitment to building mutual trust and confidence in their net-zero ER targets by providing information that improves clarity, transparency, and understanding of the NDC. The marginalized actors also need clarity, transparency and understanding on how the NDC ensure their protection from socio-ecological inequalities.

The concept of climate mitigation actions

Despite the concept of ecosystem-based solutions having historically featured in the Global Climate regime since 1992 at the United Nations Conference on Environment and Development, its definition was first published by the World Bank in 2008. This definition encompass the range of climate change mitigation and adaptation co-benefits that accrue from investments in the conservation of biological diversity^[70]. It was then featured in IUCN’s position paper of 2009 to the CoP 15 of the UNFCCC^[71] and its 2013-2016 program^[71]. In all cases, the concept was used to position the role of Reduced Emissions from Deforestation and forest Degradation (REDD) and other ecosystem-based solutions in climate mitigation and adaptation. It included climate change actions that secure water, food, and energy to reduce poverty and induce economic growth. The concept then emerged in the publications of the European Union to frame opportunities that harness nature through innovative and cost-effective ways to deliver environmental, social, and economic benefits^[72].

The concept of ecosystem-based solutions has evolved to encompass different concepts and approaches that help protect, conserve, and restore forests and other terrestrial and marine ecosystems to deliver climate, environmental, social, and economic benefits^[14]. These different concepts include the ecosystem approach, ecological restoration of forest and landscape, ecological engineering, agro-ecology, ecosystem-based adaptation, REDD, ecosystem-based disaster risk reduction, green infrastructure, and natural climate solutions^[73-75].

The literature frames the concept of ecosystem-based solutions to global climate change as activities that protect, conserve, restore, manage, and enhance the integrity of natural ecosystems with the aim of reducing GHG remission, strengthening adaptive capacity and climate-resilience, and reducing vulnerabilities of the marginalized to adverse effects of climate change under the context of sustainable and inclusive development outcomes^[1-22,76,77]. Thus, in addition to direct ER benefits, ecosystem-based solutions have the potential to provide multiple mitigation co-benefits from adaptation, resilience to climate change, and economic diversification^[76,78,79]. Other non-carbon co-benefits include the conservation of biodiversity^[79,80], securing ecosystem services^[18], provision of livelihoods for local communities and indigenous peoples^[79,81], and restoration and management of landscape that are vulnerable to the effects of climate change^[82,83].

At the Earth Summit in Rio in 1992, ecosystem-based solutions were framed as global commons that serve as sinks for the GHG emissions in the global atmosphere. They include different types of ecosystems including forests, marine, agriculture, wetlands, peatlands, and mountainous ecosystems^[24-26,84]. However, the framing of global commons failed to appeal to governments of DCs, environmentalists, and climate justice groups whose understanding, approaches, and interests in ecosystems differed from the rich industrial countries and multi-national corporations with economic interests in ecosystem services. Human rights advocates perceived and feared that the notion of globally governing ecosystems of nature resources that are within their national territories, such as forests and marine resources would threaten the marginalized global south regions, countries, sectors, places, ecosystems, and social actors. Governments feared the historical attempts by the former colonizers, now industrial global north, would open new waves extra-territorial intrusion and exploitation of their natural resources to finance the economic growth of the rich. Environmentalists feared the threats from the conversion of natural ecosystems such as natural forests whose carbon stocks and biodiversity are richer than in forest plantations^[28,85,86].

The the Kyoto Protocol of 1997 while developing the Clean Development Mechanism, such as afforestation, excluded ecosystems-solutions like natural forests due to a lack of solid science to measure forest-related emissions^[87-89]. Yet, afforestation was laden with criticisms of potential attempts to convert natural forests to forest plantations, thus threatening the livelihoods of local communities and indigenous peoples and environmental integrity, including the conservation of biodiversity and natural landscape^[88,90,91]. The Kyoto Protocol ended in 2012 but found its way into the Paris Agreement having not elaborated on safeguards for tackling historical global constellations of socio-ecological concerns^[92-94].

The concept of ecosystem-based solutions emerged in the formal UNFCCC negotiations under two policy mechanisms. The first mechanism focused on the policy approaches and positive incentives for activities relating to REDD and their role in promoting conservation, sustainable forest management, and enhancing forest carbon stocks in developing countries. The second mechanism involved alternative policy approaches, such as joint mitigation and adaptation (JMA) approaches, aimed at integral and sustainable forest management^[95]. These global climate policy approaches evolved over a long journey, from 2005 to 2051, when they were integrated into the Paris Agreement. They are involved through lengthy UNFCCC Conference of Parties decisions between the rich and poor countries and corporations, and civil societies such as environmentalists and human rights while trying to address potential socio-ecological concerns witnessed under afforestation ER projects under the Kyoto Protocol^[37,96,97]. Although the methodological issues were solved, challenges in elaborating and applying safeguards have persisted as evident in the prevailing constellations of global trends and patterns of related inequalities^[27,31,98].

The Paris Agreement of 2016, under Article 5, incorporated REDD and JMA as major ecosystem-based solutions for balancing emissions by sources and removals by sinks thereby, helping to achieve net-zero ER

target and the long-term global temperature goal by 2050^[166,99,100]. Subsequent decisions by the UNFCCC, including the Glasgow Climate Pact under CoP 26 and the Sharm El Sheikh Climate Change under CoP 27, have continued to reaffirm the concept of ecosystem-based solutions, emphasizing the use of terrestrial and marine ecosystems to reduce GHG emissions from sources and enhance removals by sinks, while simultaneously delivering mitigation co-benefits from adaptation and economic diversification^[24,25].

Table 2 presents some GHG emissions sources, categories, effects, and mitigation measures. The IPCC (2006) categorized ecosystem-based solutions, including forests, wetlands, coastal and marine ecosystems under the IPCC sectors of land use, land cover change, and forest (LULUCF) and agriculture activities into crop and livestock systems. Ecosystems are part of the climate mitigation actions commonly featured in most of the Nationally Determined Contributions submitted to the UNFCCC secretariat.

THEORETICAL FRAMEWORK

The concept of sustainable and inclusive development (SID) evolved from scholarly works and is gaining momentum among policymakers and development practitioners. It aims to address the challenges of balancing the three dimensions of sustainable development. The concept of SID instead unveils social, environmental, and relational aspects while tackling trade-offs from economic aspects.

This section reviews the literature on sustainable and inclusive development to draw insights on the principles of social sustainability and inclusiveness (see Section "The concept of socio-ecological inequalities"), ecological sustainability and inclusiveness (see Section "Principles of social sustainability and inclusiveness"), and relational sustainability and inclusiveness (see Section "Principles of relational sustainability and inclusiveness").

The concept of socio-ecological inequalities

Since 2003, non-state actors have provided experience in shaping the governance of ecosystem-based voluntary carbon offset markets through network of private investors, carbon credit registries, standards, and GHG inventory and accounting methodologies^[115-118]. The Global Climate Change regime, through the Paris Agreement^[1], the Glasgow Climate Pact^[2], and the Sharm El Sheikh Climate Change Conference^[4], has heightened the call for private enterprises, financial institutions, and regional and city authorities for economy-wide, deepened, and far-reaching ER beyond the public sectors while closing the financial flow gap currently limiting ER ambitions for DCs under UNFCCC mechanisms.

Despite these mitigation and financing benefits, the implications of introducing new power dynamics from the non-state actors to the already existing asymmetrical powers between the rich and poor countries further confound efforts to tackle historical and new socio-ecological inequalities. These implications have dominated scholarly, policy, and advocacy discourses. These concerns largely stem from global constellations of historical trends and patterns of climate injustices that violates the rights of indigenous peoples and local communities. This is through forced evictions, denial of access to natural resources that are a source of livelihoods, and inequitable sharing of opportunities, responsibilities, rights, and risks. In addition, the historical accumulation of the ecospace and natural resources from ecosystems leads to unequal distribution of opportunities and wealth. The grabbing and exploitation of ecosystems by the rich subjects them to the degradation of natural ecosystems, loss of biological diversity, and damage to the natural landscapes. Moreover, it compromises the credibility and value of emission credits due to socio-ecological trade-offs^[82-85]. Although ecosystem-based solutions has been acknowledged as being historically viable and cost-effective, certain actors argue that their intricate relationships to the livelihoods of poor and

Table 2. GHG emissions sources and mitigation interventions

GHG sector	Ecosystem-base actions	GCC effects	Interventions	Reference
LULUCF	Forest ecosystems	GHG sources and sinks/removals	Sustainable forest management, reduced deforestation and forest degradation, forest conservation, forest enhancement: afforestation, reforestation, revegetation	[101,102]
	Wetlands	GHG sources and sinks	Protection and conservation	[103]
	Coastal and marine ecosystems	GHG sinks	Protecting marine coral reefs, seagrass, and coastal ecosystem (mangrove restoration and conservation)	[104-106]
Agriculture	Livestock	GHG sources	Improved management of manure; improved diets and feeds; improved breeds	[99,107, 108]
	Agronomy	Sources and sinks/removals	Improve rice, Burning of agricultural waste	[109-111]
	Agronomy	Sources and sinks/removals	Improve rice, Burning of agriculture waste	[56-58]
Energy	Decarbonization	GHG sources, avoidance, and removals through technologies	Energy efficiency, Energy shift, waste-energy conversion, fluorinated gas substitution	[112-114]
Industrial Process and Product Use	Iron, steel, and metallurgical coke; Fluorinated substances; others - military, research, industrial and medical particles	GHG sources (fuel transformation; fugitive emissions; flaring emissions; venting emissions)	Iron and steel production (Blast furnace) Fluorinated substitute (textile, carpet, leather, papers); Others (researcher accelerator, industrial and medical particle accelerator); Products (refrigerators, foams, or aerosol cans)	[38,59]
Waste	Municipal solid waste, sludge, industrial waste, other waste	GHG sources -open dumping and burning	Energy recovery from waste; restrict choices for ultimate waste disposal; promote waste recycling and re-use; encourage waste minimization; mitigation co-benefits from policies and measures in waste sector	[60]

marginalized social actors and the trade-offs from power dynamics between the rich and poor may undermine use to achieve net-zero ER targets under the context of climate justice.

Thus, the politics of development argue on the need to address trade-offs by decoupling and examining the implications of economic growth in the governance of ecosystems-based solutions with a view of tackling potential socio-ecological inequalities^[30,119-121]. The concept of sustainable and inclusive development attempts to unveil the neoliberal ideological framings of the market and economic growth that the concept of sustainable development has been unable to decouple. It also highlights its inherent power politics, which are also found in other related concepts such as the green economy or green growth by UNEP and the World Bank^[112,113], inclusive wealth by UNEP and UN-IHDP^[114,122], and inclusive economics by the Rockefeller Foundation^[123]. In essence, the concept of SID provides insights into how development can be pursued in ways that ensure discrete yet integrated social, ecological, and relational sustainability and inclusiveness to help in addressing the potential socio-ecological inequalities common in the governance of ecosystem-based solutions to the problem of global climate change.

Some critics perceive these solutions as technologically immature and burdened with technocratic and bureaucratic barriers that hinder their effective development and adoption under the context of sustainable and inclusive development^[14,15,22]. Consequently, the governance of ecosystem-based solutions in the absence of adequately elaborated safeguards has the risk of perpetuating socio-ecological inequalities that disproportionately impact on marginalized sectors, places, ecosystems, and social groups

Principles of social sustainability and inclusiveness

Social sustainability and inclusiveness deal with strategies for empowering the poor to participate and fairly share the benefits of development. They call for global development policies to be contextually sensitive by investing in the human and social capital of the poor^[34,124]. The aim is to enhance their capacity to participate in opportunities for development^[121,125-127]. It argues that participatory governance in all aspects of

development^[128-130] and contend that capacity building of the poor and marginalized social actors enhances their opportunity to participate in the politics of development^[35,131].

Social sustainability and inclusiveness require adopting five principles: (a) the principle of equitably sharing of opportunities and benefits from development; (b) including the knowledge of the marginalized in defining the development process and goals; (c) building the targeted capacity of the poor to enable them to effectively participate in and benefit from development opportunities that they would not have otherwise accessed; (d) setting social protection floors for the most marginalized; and (e) engaging the marginalized in the politics of development.

Principles of ecological sustainability and inclusiveness

Ecological sustainability and inclusiveness deal with strategies for reconciling ecological issues and the needs of the poor and marginalized. They argue for the need to protect local, national, and trans-boundary ecosystems and ensure access, ownership, and participation of the marginalized in the governance of these resources. They seek to ensure that ecosystem services are well managed and governed in a manner that prevents the transfer of any harm to trans-boundary and regional ecosystems. They also seek to set and avoid practices that exceeds multiple ecological limits^[132,133].

Ecological sustainability and inclusiveness can be enhanced through a vision of prosperity and well-being within the context of multiple eco-centric limits and targets. They call for equitable allocation of rights, responsibilities, and risks to all, as well as the greening of financial development assistance instruments and trade institutions^[134,135]. It promotes five principles: (a) adopting multiple sets of eco-centric limits that are contextually relevant and internally consistent; (b) ensuring equitable sharing of rights, responsibilities, and risks; (c) ensuring adequate legal protection and building resilience and adaptive capacity; (d) greening international cooperative instruments; and (e) engaging relevant stakeholders in defining and implementing these green instruments.

Principles of relational sustainability and inclusiveness

Relational sustainability and inclusiveness deal with strategies for addressing drivers of inequalities, exclusion, the abdication of responsibilities, and marginalization^[136,137]. They argue that the rich have become richer through historical accumulation and continued concentration of eco-space and wealth, achieved through direct and indirect exploitation of natural resources and heavy investment in sinks and intellectual property rights, including medical patents^[36,138,139]. The principles question tax avoidance and evasion through virtualization and offshoring of trade in ecosystem resources and services. In addition, they lobby for small governments and deregulation of trade and markets. The rich often have tendencies to bypass legitimate governments to access these ecosystem resources and services within the jurisdiction of poor countries. Similarly, they evade participatory governance processes, thereby preventing the poor and marginalized from accessing and benefiting from the otherwise legitimately own^[140-142].

Relational sustainability and inclusiveness seek to address structural inequalities. They undertake scholarly engagements through diverse analyses and evidenced-based discourses that counter dominant and biased narratives, which exclude the marginalized from owning and accessing ecosystem-based livelihoods. Social movements including epistemic communities, communities of practice, and the media networks can potentially bring to the attention of policymakers the prevailing drivers and actors who promote inequalities. They also call for policy reforms to address the disparities of power dynamics between the rich and poor^[22,26-35].

It is, thus, enhanced through five principles, which include: (a) developing specific rules to ensure that public goods are not privatized and securitized; (b) addressing all drivers and actors who lead to the accumulation of wealth and eco-space; (c) challenging discourses that concentrate wealth; (d) ensuring instruments are inclusive and fostering downward accountability of institutions; and (d) promoting the global rule of law and constitutionalism.

The insights from sustainable and inclusive development principles are used to design the safeguards elements and indicators of the ECMAS Indicator Framework (see Section "BUILDING THE ECMAS INDICATOR FRAMEWORK"). The safeguards elements and indicators are used to examine the extent to which countries provide information for improved clarity, transparency, and understanding on the rules, guidelines, and procedures that countries plan to use tackle potential socio-ecological inequalities under net-zero emission reduction targets, thereby ensuring sustainable and inclusive development outcomes.

BUILDING THE ECMAS INDICATOR FRAMEWORK

Figure 2 presents the methodological approach for building and applying the ECMAS Indicator Framework. The framework was built through six steps based on insights from the review of scholarly literature and policy decisions.

First, we brought together the identified NDC structural elements including Paris agreement goals, net-zero ER targets (see Section "The concept of net-zero emissions reduction targets"), climate mitigation actions (see Section "The concept of climate mitigation actions"), and safeguards measures (see Section "THEORETICAL FRAMEWORK"). Second, we elaborated these NDC structural elements and into 12 indicators and 38 sub-indicators, as shown in Table 3, for information to improve the clarity, transparency, and understanding of the NDC^[1,5,6]. Third, we elaborated on "Paris Agreement goals" as consisting of 5 indicators and 6 sub-indicators. The information consisted 5 goals including temperature, mitigation, adaptation, adaptation, financial flow and clusters of sustainable development goals. Fourth, we elaborated the "net-zero ER targets" as consisting of 3 indicators and 11 sub-indicators of information. The information indicators include quantifiable reference point(s) and levels, timelines and period, and coverage and scopes of ER. The sub-indicators include reference points and timelines or level; coverage of GHGs, scope sectors, categories activities and pools, and mitigation co-benefits from adaptation and economic diversification.

Fifth, we elaborated the climate mitigation actions to consist of 2 indicators and 11 sub-indicators of information for improve clarity, transparency, and undertaking on the process, assumptions and methodologies preparing and implementing ER measures. The indicators include planning process and assumptions and methodological approaches. The sub-indicators on planning process were elaboration to include information on contextual matters, domestics instructional arrangements, policy measures and initiatives, ecosystem-based solutions; decarbonization technologies, adaptation and climate resilience, loss and damage, support system, climate empowerment action, and voluntary cooperation mechanism. The sub-indicators on assumptions and methodological approaches were elaborated to provide information how the experience on NDC can inform the global stocktake, reporting guidelines, process of estimating emissions, process of constructing emissions, and estimation estimating climate forcings. Sixth, we elaborated the safeguards measures was elaborated using 2 indicators and 11 sub-indicators on information on rules, guidelines, and procedures for ensuring climate justices. The indicators include fairness and ambitiousness of ER targets and measures, and alignment to the objectives of the convention. The sub-indicators include social, ecological, and relational fairness and equity; ambition of ER measures, and how the NDC is contributing to the achievement of the long-term temperature goal and sustainable development goal^[1,2,5,6,48].

Table 3. Elements for building NDC ECMA5 indicator framework

Components	Criteria	Indicators: information for improved clarity, transparency, and understanding of NDC
Net-zero Emission Reductions (ER) Targets	1.1 Quantifiable reference point(s) and indicators	Quantified reference points (s) and indicator(s): Reference year(s), base year(s), reference period(s) or other starting point(s) Level of emissions reductions: "Business-As-Usual (BAU)" Reference levels Projected emission reduction levels <i>Sources of data used to quantify reference points</i>
	1.2 Timelines or periods	Timelines for <i>reference points</i> Start and end date of implementation
	1.3 Scope and coverage	<i>General description of the target:</i> sectors, gases, categories, and pools Coverage of gases: <i>Main GHGs:</i> carbon dioxide (CO ₂), methane (CH ₄), nitrous oxide (NO), <i>other gases:</i> black carbon (mono-nitrogen oxide), non-methane volatile organic compound, sulfur dioxide, chlorofluorocarbon, sulfurfluorocarbon, hexafluorocarbon, and perfluorocarbon, short-lived climate forcers <i>Sector:</i> energy, agriculture, forestry, and other Land use, industrial process and product use and waste <i>Categories:</i> Specific activities: afforestation, reforestation, REDD-plus, cyclic economy, livestock system, cropping system, energy efficiency
Climate Mitigation Actions	2.1 Planning process	<i>Contextual matters:</i> Geography, climate, economy, sustainable development, and poverty eradication; best practices and experience, contextual aspirations, and priorities. Regional economic integration organizations and their member states <i>Domestic instructional arrangements,</i> actors, and gender <i>considerations,</i> public participation and engagement with local communities and indigenous peoples, and gender-responsiveness <i>Policy measures and initiatives:</i> economic and social consequences of response measures <i>Nature and ecosystem-based solutions:</i> Land use systems, landscape management, Forest: afforestation, REDD-plus, Agriculture: agronomic and livestock management practices, Wetlands, Marine, fisheries and aquaculture management <i>Decarbonization technologies for emissions reduction:</i> Energy efficiency, Shift to renewable energy, adapt industrial and agricultural processes, energy efficiency and managing demand, adopt circular economy, reduce consumption of emissions-intensive goods, deploying carbon capture, utilization, and storage (CCS) technology, and enhance sinks (long-lived and short-lived GHGs) <i>Decarbonization technologies for carbon dioxide removal from sources or atmosphere:</i> (a) natural carbon removal e.g. reforestation and forest management, farms and soils; (b) biomass carbon removal and storage, biochar, bio-oil, vaults; (c) bioenergy carbon capture and storage - converting biomass to hydrogen; (d) direct air capture - scrubbing CO ₂ from the air and sequesters it underground or in long-lived products like concrete; (e) carbon mineralization; and (f) ocean-based Approaches <i>Mitigation co-benefits</i> from adaptation plans and/or Economic diversification actions: Description of strategies, policies, plans and actions for low emissions, adaption, and climate-resilience <i>Support system:</i> Capacity building, technical skills, technological demonstration, and transfer, financial, programs, and projects <i>Climate empowerment action:</i> Education, training, public awareness, public access to information, and international cooperation <i>Voluntary cooperation:</i> Intention to use voluntary cooperation mechanism
	2.2 Assumptions and methodological approaches	<i>Experience:</i> How NDC preparation is informed by the outcomes of the global Stocktake Existing methods and guidance under the Convention and IPCC methodologies and metrics used to estimate GHG Process of estimating emissions by sectors, categories, and activities consistent with IPCC guidance Process of constructing emissions by sources and removals from natural disturbances on managed lands; effects of age-class structure in forests, the process of constructing Information on estimating climate forcers not covered by IPCC guidelines is estimated
Safeguards for the marginalized	3.1 Fair and ambitious	<i>Ambition:</i> Highest possible ambition, Economy-wide emission reduction or limitation targets, Strategies, plans and actions for low GHG emissions development <i>Social principles:</i> Fairness considerations, including the principle of equity principles of equity, gender considerations, Indigenous peoples, and local communities <i>Ecological principles:</i> Environmental integrity; protection of biodiversity conservation, and nature forests; and adaptation and climate resilience <i>Relational principles:</i> Rules against greenwashing
	3.2 Contributes to the convention	<i>Long-term temperature goal:</i> Information on how the NDC contributes to GHG reduction and stabilizing temperatures

Source ^[1,2,5,6,48,143,144]

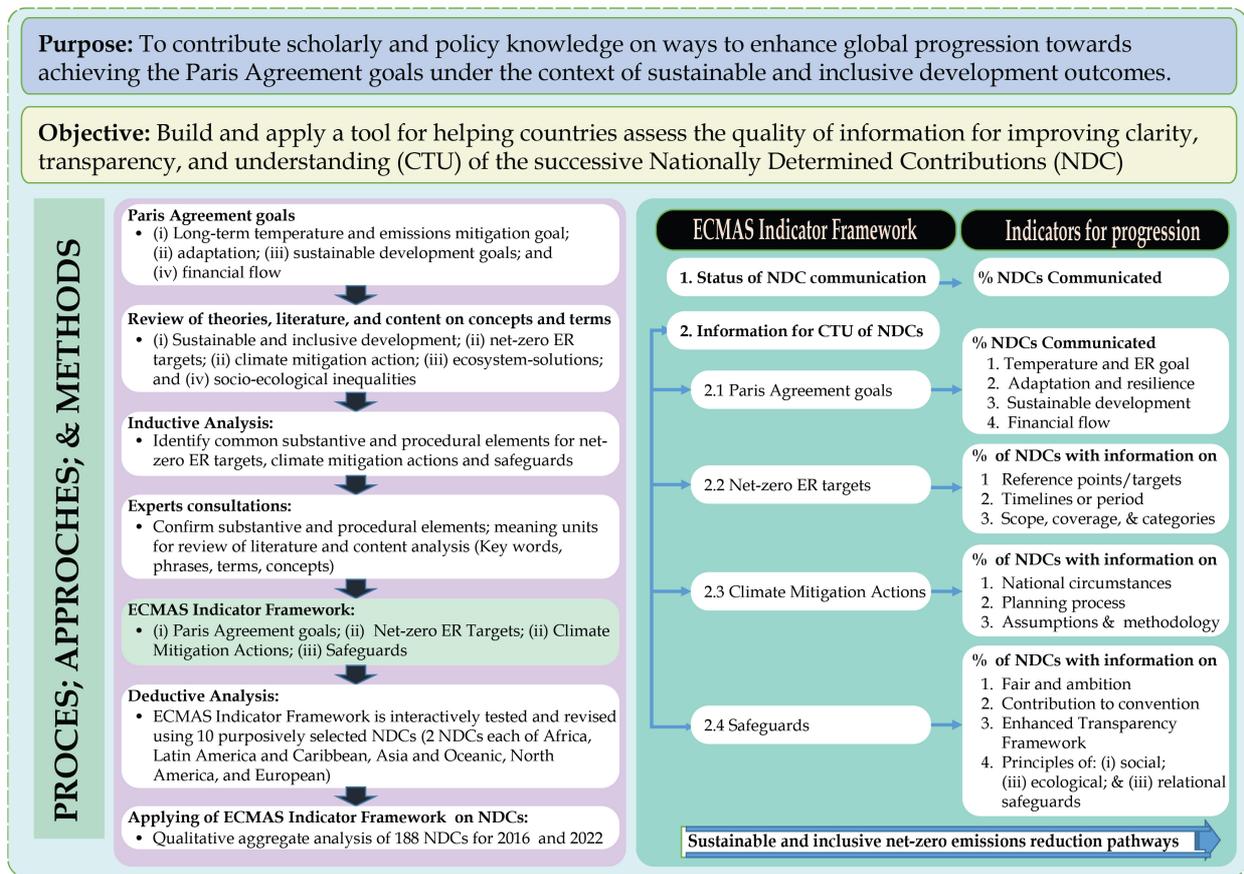


Figure 2. Methodological approach to building the ECMAS Indicator Framework^[43-46]. Sources: Review of literature and policies on climate change governance IPCC^[45-49], UNFCCC^[43,44,50], FAO^[22], WWF^[39,44], WBCSD and WRI^[41], and World Bank^[74,80].

Validation of the ECMAS indicator framework

The framework was subjected to an online consultative session with subject matter specialists in physical science; GHG sectors including energy, agriculture, forestry, waste, industry, and marketers; adaptation and climate-resilience; and social and environmental safeguards. The aim was to seek the contribution of these experts in refining the identifying, selecting, framing, and organizing the elements and indicators for assessing the quality of information provided by countries to improve the clarity, transparency, and understanding of NDC in delivering net-zero sustainable and inclusive development outcomes. The framework was deductively applied to 10 NDCs purposefully selected from Africa, Latin America and the Caribbean, Asia and Oceania, North America, and Europe. The insights were integrated into the ECMAS framework. The finalized framework and tools were applied to 188 successive NDCs communicated to UNFCCC from 2016 to 2018 and from 2018 to 2022.

Aggregate analysis

The ECMAS Indicator Framework was applied in the aggregate analyses of the NDCs communication process and quality of information in the successive NDCs through six steps. First, the Parties to the UNFCCC were identified from online databases. The analyses examined, based on five global regions, the trends and, patterns in Parties communication of NDC over the period 2015 -2018 and 2018 to 2022. Data was obtained from the NDC registry hosted on the UNFCCC secretariat website. The timelines over which the NDC were communicated was recorded. Second, an analysis was undertaken to determine the quality of

information provided in the successive NDC for improving clarity, transparency, and understanding of the indicators for net-zero ER targets, climate mitigation actions and safeguards. The analysis was based on the summary of information provided at the end of each NDC and counter-checking it with the main content. [Table 4](#) provide the scoring matrix on the quality of the information provided in terms level of consistency, explanation, and examples of the concepts, terms, and indicators provided based on the IPCC and UNFCCC guidelines.

Third, the threshold for determining whether the quality of information provided was reasonably adequate in ensuring clarity, transparency, and understanding of the NDC was set at a score of 0.75. The indicators with lower scores were excluded from the aggregate analysis. Fourth, the indicators with at least a score of 0.75 were filtered and included in the aggregate analysis while excluding those that had a lower score. Fifth, an aggregate analysis was undertaken to determine the proportion of Parties that achieved the set information quality threshold. The details of the analysis consisted of the proportion of Parties that achieved the set threshold for each indicator and sub-indicators. The results were expressed using the following qualifiers: “a few” for 0.5%; “some” for 25%; “several” for 50%; “most” for 75%; and “most” for 90%. The results were presented in tabular or chart formats. The results were used to depict the most plausible sustainable and inclusive net-zero ER pathways that countries can pursue collectively achievement of Paris Agreement goals under the context of sustainability and inclusive outcomes.

RESULTS

This section present findings derived from the aggregate analysis of the proportion of countries that provided information of appreciable quality, with at least a score of 0.75, for improved clarity, transparency, and understanding of the indicators with in the NDCs. The results from the application of the ECMAS Indicator Framework (see [Figure 2](#)) were summarized and presented in tabular and chart formats. The results includes global trends and patterns on NDCs communication (see Section "Global trends and patterns in NDC communication"), Paris Agreement goals (see section "Paris Agreement goals"); net-zero ER targets (see Section "Enhanced net-zero emission reduction targets"); climate mitigation actions (see Section "Enhanced climate mitigation actions"); safeguards for the marginalized (see Section "Enhanced safeguard measures for the marginalized"); and constructing appropriate sustainable and inclusive net-zero ER pathways (see Section "Constructing appropriate sustainable and inclusive net-zero ER pathways").

Global trends and patterns in NDC communication

[Table 5](#) presents the results of NDCs communicated to the UNFCCC secretariat. As of 2022, there were 198 parties to the CoP of the United Nations Conference on Climate Change. Between 2016 and 2022, a total of 188 INDCs and NDCs were communicated and registered on the UNFCCC public portal. These include 141 NDCs communicated by DCs, 29 INDCs communicated by the European Union (EU), including one for itself and 28 for the member states, 14 NDCs by parties in the Europe region but not members of the European Union, and 2 NDCs from Northern America. Notably, about 86 updated or new NDCs were communicated by 113 parties, which include 112 states and the EU.

Notably, the countries in Africa, Asia, Latin America, the Caribbean, and Oceania took more time, in the range of four years, to communicate their INDCs and NDCs, while North America and Europe took less time, in the range of two years. This may be attributed to the low capacity concerning competencies, financial availability, technology development, and technical skills for preparing the INDCs and NDCs.

Paris Agreement goals

[Figure 3](#) shows overall aggregate progression (+44%) in providing quality of information on the Paris

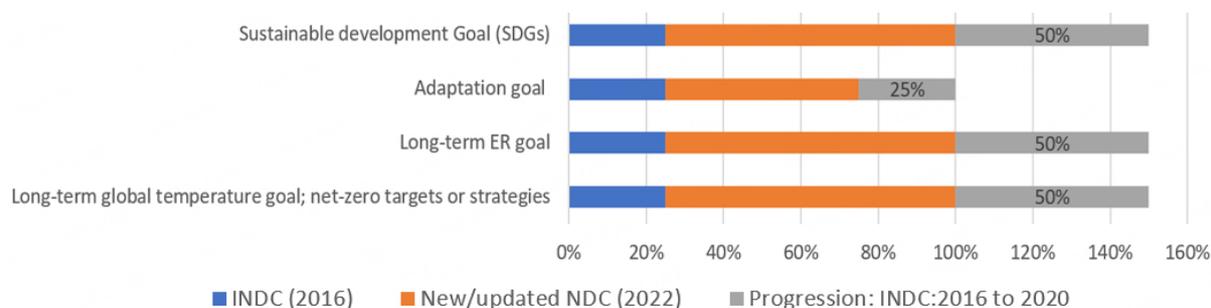
Table 4. Scoring schema for adequacy of information provided in the NDCs

NDC analysis	Score and Symbol	Quality of information provided
NDC submissions	Symbol	
INDC: 2016	Yes = 0; No = 1	INDC of 2016 is Communicated; INDC is NOT Communicated
New NDC: 2022	Yes = 0; No = 1	NDC of 2022 is Communicated; INDC is NOT Communicated
Updated NDC:2022	Yes = 0; No = 1	NDC of 2022 is Communicated; INDC is NOT Communicated
Indicators	Score	
Quality of information: level 1	Score = 0	NO Team; NOT Explained; NO Example
Quality of information: level 2	Score = 0.25	INCONSISTENT Terms; NOT Explained; NO Example
Quality of information: level 3	Score = 0.50	CONSISTENT Terms; NOT Explained; NO Example
Quality of information: level 4	Score = 0.75	CONSISTENT Terms; Explained; NO Example
Quality of information: level 5	Score = 1.00	CONSISTENT Terms; Explained; Example

Table 5. Number of NDCs communicated from global regions and timelines

Region	INDC (2016-2018)		First NDC (2018-2022)	
Africa	51	(22/04/2016-30/10/2018)	51	24/10/2022-20/05/2020
Latin America and Caribbean	34	(18/04/2016-20/03/2019)	34	30/12/2022-13/02/2019
Asia	40	(22/04/2016-22/05/2019)	40	30/01/2023-28/12/2020
Oceanic	16	(09/11/2016-24/03/2016)	16	02/03/2023-31/12/2020
North America	2	(03/09/2016-05/10/2016)	2	(22/04/2021-12/07/2021)
Europe	43	(20/06/2016-26/09/2018)	43	08/11/2022-07/02/2020
Total	188		188	

Source: NDC Registry. Available from: <https://unfccc.int/NDCREG>.

**Figure 3.** Progression towards achieving Paris Agreement goals.

Agreement goals (2016: 25%, 2022: 69%). The analysis examined 5 indicators including temperature, mitigation, adaptation, financial flow, and UN sustainable development goals. Several countries showed progression in the quality of information on the Paris Agreement goals. However, some NDCs used mixed terms including long-term vision, goal, targets, and strategies. Adaptation was the least elaborated goal which implies only some countries provided sufficient information to ensure the safeguarding of the marginalized places, sectors, ecosystems, and social groups from the adverse effects of climate change.

Enhanced net-zero emission reduction targets

This section briefly discusses the patterns in the information provided to describes terms referring to net-zero ER targets.

Terms used on net-zero emission reduction targets

Figure 4 shows the patterns on the terms used across the NDCs to describe the concept of net-zero ER target. Overall, several countries (41%) frequently used 8 out of about the 20 terms found across the NDC to describe net-zero targets. Most Parties used net-zero GHG emissions reduction while several used net-zero emissions, net-zero carbon emissions, carbon neutrality, and absolute emission reduction; and some used balancing of anthropogenic emissions by sources and removals. About 60% of the countries did not provide sufficient information that reflected net-zero ER targets. This makes it difficult to determine their ambitions and progression towards achieving net-zero ER targets and relevance of their mitigation efforts.

Information on net-zero emission reduction targets

Figure 5 shows overall aggregate progression (+26%) on providing quality of information provided on net-zero ER targets (2016: 60%, 2022: 35%). It assesses 4 indicators including quantifiable reference point(s) and levels, time-frame and period(s), coverage of GHGs, and scope of GHG sectors which are elaborated in 27 sub-indicators. Most countries have committed to "peaking" of GHG emissions over the period 2025 to 2030, followed by further ER of between 43% relative to 2010 and 45% relative to 2019 estimates by 2030, then to achieve net-zero ER by 2050, and finally attain climate neutrality by 2100. Some NDCs provided information on long-term mitigation vision, strategies, and targets for up to and beyond 2050. About 30% of the NDCs provided elaborated for achieving net-zero ER targets by 2050, while 2% provided plans for the period between 2050 and 2100. Around 34% of the NDCs only indicated intentions to achieve a net-zero target by 2050, while 1% provided plans for the period 2050 to 2100. Also, 2% of NDCs indicated the intention to achieve net-zero targets without providing timelines, and about 31% did not provide net-zero targets.

Notably, only 70 parties provided information on the commitment to achieve carbon neutrality by midcentury. Estimates indicate that this would lead to a reduction in ER by 30% over the period up to 2030, based on 2010 baseline estimates, under the scenario of limiting the increase in global average temperature to 1.5 °C above the pre-industrial levels. However, despite these ER levels, the remaining 106 NDCs either showed an increase or no reduction in ER, which will lead to a substantial increase in aggregate GHG emissions by about 20% over the same historical timelines and scenarios. In addition, 12 parties, including Australia, Brazil, Ethiopia, Indonesia, Mexico, the Philippines, the Russian Federation, Singapore, Switzerland, Thailand, The Gambia, and Vietnam, did not demonstrate any additional GHG reduction ambitions. Some countries also indicated intentions to update their net-zero ER targets or noted that they will only re-communicate the targets of 2020 in their future updated or new NDCs with no changes in ER ambitions.

Although there is significant progression in the provision of quality of information on net-zero ER targets across the NDCs, a high number of countries' climate action plans still do not demonstrate commitment to achieving net-zero ER targets. Additionally, there are numerous inconsistencies regarding net-zero ER levels and timelines. The NDCs express net-zero ER targets using terms such as climate neutrality, carbon neutrality, GHG neutrality, or net-zero emissions. Notably, there is a low emphasis on short-lived climate pollutants and radiative forcers. Their combined effects on global warming and environmental pollution pose a threat to the climate system and are associated with human health concerns. The CCAC literature has argued that the increased levels of short-lived climate pollutants and radiative forcers in the global atmosphere have led to about 45% of the net global warming since pre-industrial times, disrupting the climate system, especially precipitation patterns, damaging ecosystems, and causing health concerns, including heart and respiratory complications.

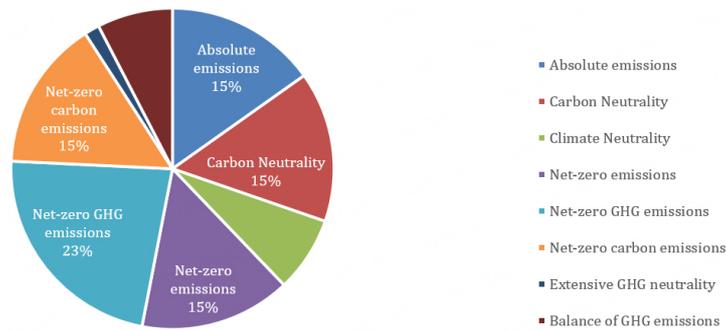


Figure 4. Terms used to express net-zero ER targets.

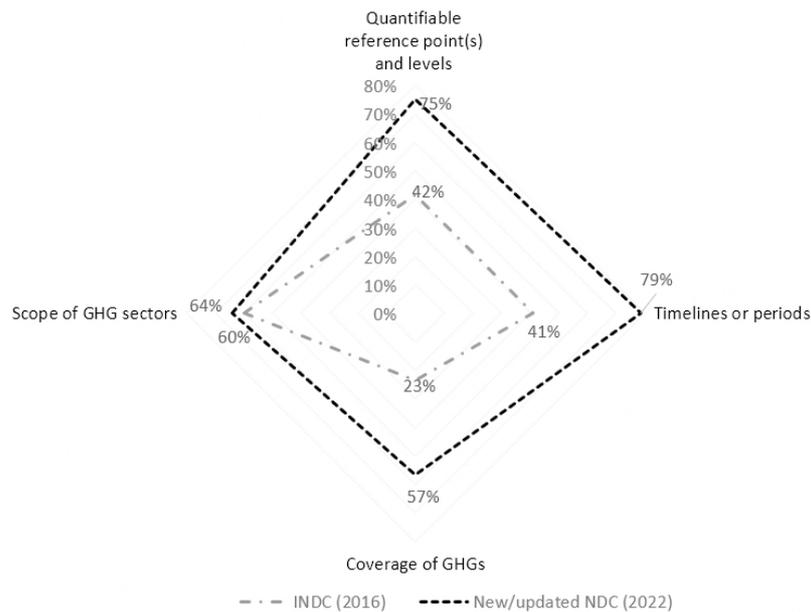


Figure 5. Progression towards achieving net-zero ER targets.

The observed inconsistencies in net-zero targets, the failure to demonstrate ER ambitions, and the low emphasis on short-lived climate pollutants and radiative enforcers might undermine aggregate global planning and progression along sustainable and inclusive net-zero ER pathways. This concern is echoed by the IPCC projections of 2022, which argue that unless NDCs demonstrate ambitious ER levels, coverage of all GHGs, and near-term timelines, GHG emissions will continue to increase, leading to a rise in the global average temperature by 2.7 °C at the end of the century. Such a global average temperature rise will be catastrophic for the planet, affecting the climate system, food security, integrity of ecosystems, and economic growth. Thus, achieving sustainable and inclusive net-zero ER targets will require countries to pursue pathways that helps to limit increase in global average temperature to 1.5 °C above the pre-industrial levels.

Enhanced climate mitigation actions

This section presents results on the aggregate analysis of the progression of mitigation actions across successive NDCs. It briefly discusses the overall ER direction and common specific and mixes of ER activities across countries that can help in determining sustainable and inclusive net-zero ER pathways.

Mitigation sectors

Figure 6 shows an overall 30% progression (+30%) between 2016 and 2022 in the proportion of NDCs providing quality information for improving clarity, transformation, and understanding of planned or developed enhanced climate mitigation sectors (2016: 50%, 2022: 80%). There is an increase in the inclusion of all IPCC GHG sectors^[36-38]. Almost all NDCs included all the IPCC sectors and related categories, such as energy supply, transport, buildings, industry, agriculture, land use, land use change, forestry, and waste. Some NDCs explained that they excluded certain sectors due to negligible or insignificant levels of ER contribution, limited technical capacity, and unavailability or inconsistency of data.

Most NDCs included renewable energy generation, improved energy efficiency to reduce energy demand, a shift to low or zero-carbon fuel through electrification of energy supply and end-use to reduce the carbon intensity of electricity and fuels, waste-energy conversion, improved manure and herds management, fluorinated gas substitution, and circular economy practices. Additionally, most NDCs included carbon sequestration in the soil or vegetation, afforestation, reforestation, re-vegetation, sustainable forest management, reduced deforestation, and forest degradation. Many NDCs prioritized reduced deforestation, such as REDD-plus activities. Some NDCs indicated measures to expand national forest cover while ensuring food security by preserving proportion of land under agriculture. Notably, almost all NDCs argued that the successful implementation of mitigation actions would depend on access to conditional financial resources, technology development and transfer, technical cooperation, and capacity-building support. Furthermore, it will depend on countries' ability to establish market-based mechanisms and the GHG absorptive capacity of ecosystems.

Almost all NDCs have included all the IPCC GHG sectors. However, there are still unmet ambitions under GHG categories across the sectors and value chains. Thus, achieving sustainable and inclusive net-zero ER targets requires ambitions that go beyond the economy-wide approach and move towards enhancing inclusivity and deepening ER at sector-specific categories along value chains and pools while addressing data availability and consistency challenges and providing technical capacity support.

Mitigation categories

Figure 7 shows an overall progression (+31%) of the countries that provided quality information for improving CTU across 23 climate mitigation categories. Several countries showed progression in agricultural activities (+55%) while some showed progression in activities under forestry (+30%), waste (+29%), energy (+26%) and marine (+29%). Notably, with regards to specific activities most countries showed progression in improved agriculture crop productivity (+70%) while several countries (+50%) showed progression in REDD option on sustainable forest management and livestock interventions on improved heard, feeds, and manure management (+50%) and electrification of transport, improved cropland management, waste-to-energy, and improved landfill system (+45%). Notably, in about 16 categories of climate mitigation activities only some countries showed progress. Thus, countries have opportunities for enhancing ambition in ER by expanding the scope of sectors and deepening ER within the categories by focusing across the value-chain and GHG pools.

Mitigation co-benefits from economic diversification and adaptation

Figure 8 shows an overall of 29% progression on information provided on mitigation co-benefits from economic diversification and adaptation (2016: 31%; 2022: 59%). Certain main sectors providing mitigation co-benefits include the agriculture sector, especially cropping and livestock production systems, fisheries and aquaculture systems, forestry sectors, energy sector, and agri-processing and product use. Interventions in cross-cutting sustainable approaches offer the highest mitigation co-benefits, followed by the agriculture and energy sectors.

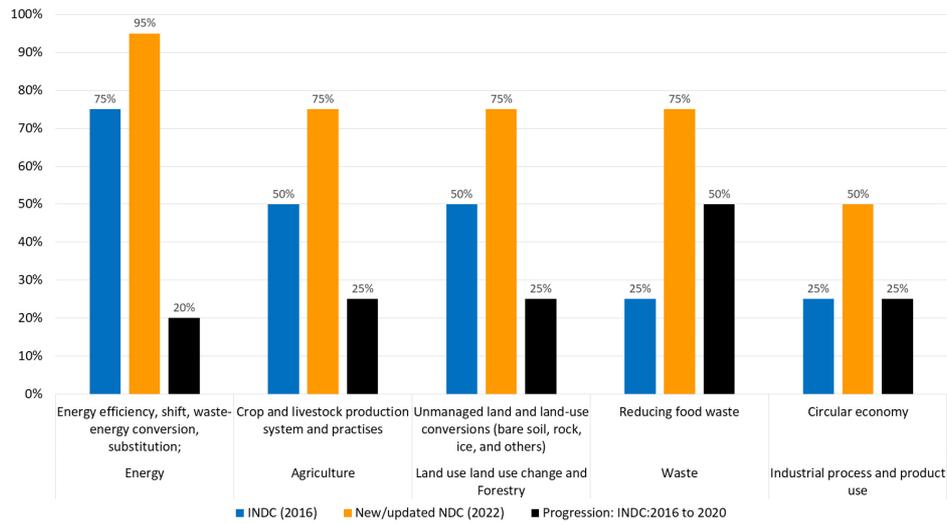


Figure 6. Progression information provided on the scope of sectors targeted for climate mitigation actions.



Figure 7. Climate mitigation categories.

Notably, although there are opportunities for mitigation co-benefits across all sectors, countries need to pursue interventions that cut across all sectors and involve all actors to ensure sustainable and inclusive net-zero ER targets.

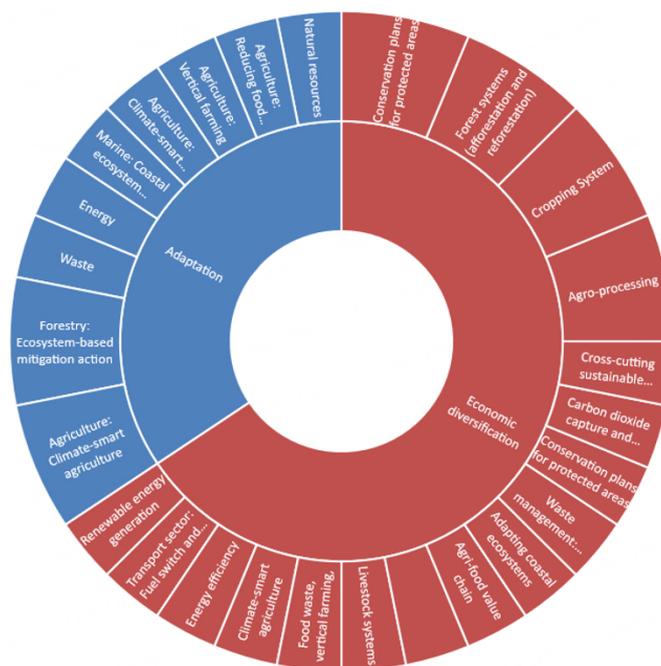


Figure 8. Mitigation co-benefits from adaptation and economic diversification.

Assumptions and methodological approaches

Figure 9 shows an overall progression (+23%) in countries that provided quality information for improving CTU on assumptions (+30%) and methodologies approaches (+17%) for GHG estimation. Specifically, many countries demonstrated progression on sector-specific parameters and use of 2006 IPCC guideline. Few countries showed progression in the information provided on assumptions about the contextual reference parameters such as GDP, population, and cost-benefit analysis; and estimates for sector, activities, baselines, tools, and models. Several countries showed progression in assumptions for methodological approaches to GHG estimation and accounting and sources of data by referencing national studies and past GHG inventories and communications. Notably, most countries are estimating their national GHG at Tier 1 level but progression while only a few are moving towards Tier 2 and none to Tier 3. Further only some countries provided quality information on the mix of metrics including GWP:100, GWP across the AR5, and GPT to compare impacts from different GHGs, and the most recent IPCC guidelines for estimating and reporting the GHG estimates 2019 refinements of 2006 guidelines. Thus, there is potential for countries to enhance ambitions by providing information on how they are progressing towards using Tier 2 and Tier 3; and improving the quality of; sources of data based on the most recent national GHG estimation studies; and contextual reference factors that influence GHG inventory process and reduction interventions.

Climate financing mechanism

Figure 10 shows progression (+38%) in the proportion of countries that provided quality information on climate financing needs, sources, allocations, estimation, and mechanisms. The aggregate analysis shows that most countries have progressed in providing information on the need for financial support to implementation of the NDC, several have progressed to quantify the levels of financing needed for mitigation and adaptation and sources, and few have progressed to provide information on the voluntary financing mechanisms. Notably, although some proportion of countries provided information on the needed financing for mitigation and adaptation under the INDC of 2016, several of them shifted emphasis to providing information on the interventions that link mitigation and SDG. Similarly, although more

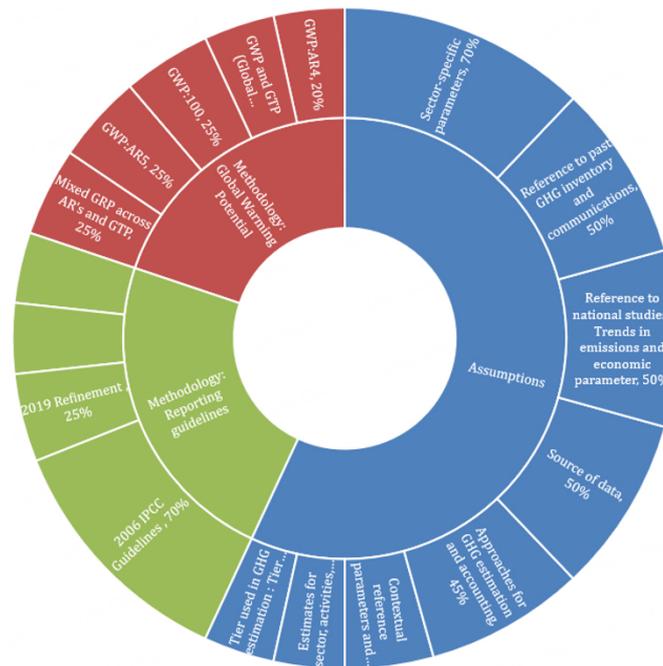


Figure 9. Assumptions and methodological approaches for estimating GHG emissions.



Figure 10. Climate financing: needs, sources, allocations, estimates and mechanisms.

countries focused on financing mitigation under the INDC of 2016, more countries focused on adaptation under the NDC of 2021. It is also noticed that although equal proportion of countries focused on providing quality information on both conditional and unconditional financing options in 2016-2018, most countries progressed to provide quality information on conditional support in 2018-2022.

This implies that countries have shifted from focusing exclusively on mitigation to more on mixed mitigation and SDG and further to adaptation. Financial mobilization is shifting more from unconditional sources, that is domestic financing, to conditional, that is international financing. This agrees with the report by UNEP^[39] that adaptation needs for developing countries are increasingly spiraling with more exposure of vulnerable sectors, places, ecosystems, and social groups to adverse effects of climate change. The report further estimates that adaptation costs in developing countries are five to ten times greater than current public adaptation finance flows, and the adaptation finance gap is widening. The current global economic and political crisis undermines climate financial flows to adaptation. This implies that countries need to explore new and innovative ways to finance adaptation needs. This could include mainstreaming adaptation in national development planning processes, domestic financing mechanisms, and implementation. Uncertainties also continued to pin-point the actual climate financial flows due to mixed targeting of mitigation, adaptation, and SDG interventions.

Enhanced safeguard measures for the marginalized

This section briefly discusses the results of the aggregate analysis of safeguards for marginalized sectors, places, ecosystems, and social actors. It covers several areas of safeguards including identifying the marginalized and developing appropriate measures for targeting, ensuring participation in NDCs' decision-making processes, dealing with governance challenges, and ensuring equitable sharing of benefits from low emission and climate-resilience pathways.

Assessing of adequacy of safeguard principles against socio-ecological inequalities

Table 6 presents findings on adequacy of safeguard principles under Paris Agreement in tackling potential inequalities from the effects of climate change and NDC planned mitigation actions. It uses the principles of sustainable and inclusive development as the normative reference. With respect to social inequalities, the safeguards principles under UNFCCC neither considers social protection nor the engagement the marginalized in politics of development. In terms ecological inequalities, the principles neither considers setting the multiple eco-centric limits to safeguard of ecosystems nor the greening of international cooperative instruments. With relational inequalities, the principles do not consider global rule of law and constitutionalism.

Identification of the marginalized sectors, ecosystems, and social actors

Figure 11 shows progression (+33%) in the proportion of countries that provided quality of information on identifying marginalized sectors ecosystems, and social actors (2016: 35%; 2022: 68%). Some of the identified marginalized places include general terrestrial, wetlands, urban areas, human habitats, and coastal and low-lying areas. The marginalized sectors include agriculture, with a focus on food systems, cropping, and livestock production systems, especially pastoralism and fisheries. In addition, the marginalized sectors encompass terrestrial and wetlands ecosystems, especially their components, such as biological diversity and ecosystems and forests, as well as economic sectors, such as energy, infrastructure, tourism, transportation, and food systems, including production and nutritional security.

Indigenous peoples and local communities

Figure 11 shows progression (+33%) in the proportion of countries that provided quality information on modalities for engaging indigenous peoples (2016: 25%; 2022: 25%) and local communities (2016: 5%; 2022: 5%). The NDCs need information based on a contextual situation analysis to describe issues on participation processes, intricate relationships, knowledge systems for conservation and adaptation, and poverty status. Additional information is needed on the status of human rights, legal measures, institutional arrangements for protecting their rights, sectoral and risk assessment and analysis, and methods for

Table 6. Principles of inclusive and sustainable development to net-zero ER goals and targets

Inequalities	Categories of principles	Achievements and limitations of UNFCCC decisions
Vulnerability and exposure to climate-related risks. Discrimination and exclusion in development processes and opportunities such as means of livelihoods, income, and assets. Social insecurity of the most marginalized	<ul style="list-style-type: none"> • <i>Social inclusiveness and sustainability</i> (i) Principles for equity; (ii) include knowledge for all; (iii) target capacity building for participation; (iv) social protection for the poor; (v) engage all in politics of development 	<p>Eradication of poverty, transition of the workforce; creation of decent work and quality job; right to health, rights of indigenous peoples, local communities, migrants, children, person with disabilities, people in vulnerable situations, right to development, gender equality, empowerment of women, intergenerational equity; action for climate empowerment; engage of all actors; consider local and indigenous knowledge.</p> <p>The UNFCCC doesn't consider social protection and engaging all in politics of development</p>
(i) Exploitation of local ecosystems that supports the livelihood of the marginalized; (ii) effects of climate change; (iii) the rich change rules of access to resources to transfer grab ecosystem and transfer resources from the poor communities; (iv) limiting GHG sinks (ecosystems capacity)	<ul style="list-style-type: none"> • <i>Ecological inclusiveness and sustainability</i> (i) Adopt multiple eco-centric limits;; (ii) equitable sharing of rights, responsibility, and risks; (iii) build resilience and adaptive capacity;; (iv) green international cooperative instruments;; (v) engage all stakeholder 	<p>Food security; environmental integrity; integrity of all ecosystem including oceans, and the protection of biodiversity conservation; protection of forests; climate-resilience; conservation and enhancement of sinks and reservoirs of GHG; build adaptive capacity.</p> <p>The UNFCCC doesn't consider multiple eco-centric limits and greening international cooperative instruments</p>
The rich invest heavily in ecosystems (sinks) by purchasing emissions rights and their resources (land rights, water rights). The rich avoid the responsibility to reduce their GHG emissions with impunity by influencing the rules of governing climate change	<ul style="list-style-type: none"> • <i>Relational inclusiveness and sustainability</i> (i) Protect privatisation of public goods; (ii) tackle instruments allowing concentration of wealth and ecospace; (iii) tackle discourses that concentrate wealth; (iv) test instruments for inclusiveness and downward accountability of institutions; (v) ensure global rule of law and constitutionalism 	<p>Climate justice, Human rights, engagement of all levels of climate governance; transparency of actions, GHG emissions estimation, and support; fairness of climate burden; respect for national legislations; avert, minimize, and address displacement related to adverse impacts of climate change.</p> <p>The UNFCCC doesn't consider all principles except global rule of law and constitutionalism</p>

engaging them in NDC planning and implementation processes. Some countries have provided information on access to finances, technology, and capacity-building support, as well as sharing modalities for the co-benefits that accrue from mitigation and competencies needed to reduce their vulnerabilities. They also include information on ways to generate payments for ecosystem services from their conservation initiatives, enhance market access for indigenous products, diversify livelihoods, and improve skills in leadership in indigenous-led climate action and negotiating for opportunities in ecosystem-based mitigation actions. A few countries clarified the role of indigenous people and local communities in climate mitigation action. They emphasized the importance of empowering them to adapt to the adverse effects of climate change, participating in climate mitigation actions, engaging them in NDC planning process, and using planning and assessment tools such as adaptation plans, decentralized strategies, livelihood improvement plans, a and ecosystem restoration strategies, as well as climate-resilience strategies to meet their livelihood needs.

Gender considerations

Figure 11 shows progression (+25%) across the successive NDCs for information provided on gender (2016: 50%; 2022: 75%). Many countries provided gender-related information, including the extent of gender mainstreaming in policies, legislation, tools, methods, and support systems. Some countries indicated the range of tools and methods for helping to mainstream gender into sectoral mitigation measures and programs. These include gender analysis or assessments, gender-disaggregated data, gender indicators,



Figure 11. Progression in information provided on marginalized sectors, ecosystems, and social actors.

gender-responsive budgeting, and gender criteria for prioritizing mitigation actions. Certain NDCs considered gender-focused capacity-building, financing, and technology development and transfer activities.

Institutional arrangements

Figure 12 shows progression (+33%) in the quality of information provided on institutional arrangements, policy instruments, principles, and tools for safeguarding against socio-ecological inequalities (2016: 33%; 2022: 53%). Most NDCs indicated that institutional arrangements help in coordinating, planning, and implementing climate mitigation actions and elaborating safeguards rules, guidelines and procedures for protecting the marginalized. Some countries highlighted in the established institutional arrangements for NDC implementation, including government entities, civil society organizations, development partners, academia, research institutions, media, trade associations, and women and youth associations. Most countries indicated the existing of inter-institutional commissions, councils, and committees for coordinating NDC implementation. Notably, few NDCs provided information on institutional arrangements for coordinating and implementing interventions on climate-induced loss and damage. A few countries indicated they have established formal institutions to ensure full and effective participation and consultation with different actors.

The NDCs do not provide information on the status of social movements, such as advocacy groups, and their role in encouraging participatory governance and capacity building to enhance such participation. Although the NDCs have also indicated the need for academia, research institutions, and media, their role in questioning discourses that encourage, lead, and protect the rich from continuing with tendencies to accumulate opportunities in net-zero ER action is not recognized.

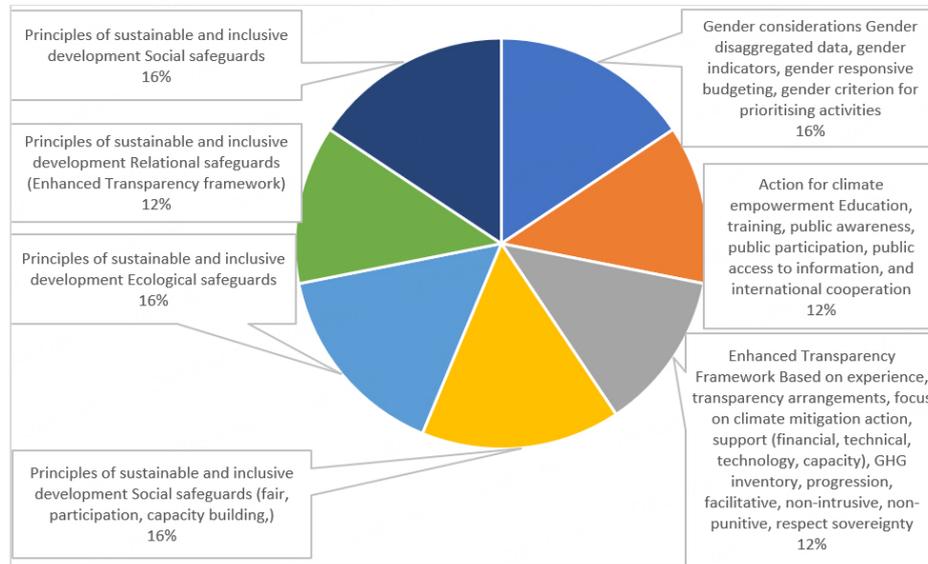


Figure 12. Safeguard institutional arrangements, principles, and tools.

Climate empowerment actions

Figure 12 shows progression (+20%) on countries providing adequate information for climate empowerment actions (ACE) (2016: 75%; 2022: 95%). The NDC has discussed six actions for climate empowerment (ACE) as provided for under the Paris Agreement. These include climate education, training, public awareness, public participation, public access to information, and international cooperation. Some countries have elaborated on the need to develop ACE-related guiding principles, national strategies, policies, and plans that help to define and implement net-zero emissions targets. Some countries have also elaborated on measures for climate education. These include policies and legislation to ensure the equitable provision of climate education, strategies for mainstreaming climate education into the national education curriculum, integrating climate mitigation action into formal, informal, and non-formal training curricula and programs, provision of training resources on climate education to instructors, and integrating climate training and re-training of stakeholders on transitioning and accessing green jobs.

Many countries elaborated on measures to raise public awareness. These include adopting actor-specific public awareness campaigns on climate education for all stakeholders, participatory designing of communication strategies, and sharing knowledge using traditional and new media. Most countries proposed strengthening institutional arrangements to ensure avenues and spaces for engaging all stakeholders in identifying the most feasible ecosystem-based mitigation actions and defining net-zero targets and processes. Some countries expressed intentions to develop regulations, systems, and tools to enhance public access to climate data and information.

Although the NDCs elaborated on action for climate empowerment, they have no information on linking institutional arrangements for net-zero ER targets and the marginalized. The NDCs do not elaborate on how ACE can be enhanced to ensure targeted capacity building to help the poor benefit from opportunities in climate mitigation and adaptation actions, engage them in politics of development, adapt to the impacts of climate change, and engage the marginalized.

Enhanced transparency framework

Figure 12 shows progression (+20%) on the proportion of countries providing adequate information on Enhanced Transparency Framework (2016: 05%; 2022: 25%). Few countries provided exclusive information on ETF. They indicated the aim of the ETF was to help in building mutual trust and confidence among multiple actors engaged in net-zero ER actions. Notably, the ETF can help countries tackle potential economic and socio-ecological concerns by dealing with power dynamics such as introduced into climate governance by call by the UNFCCC for the participation of private businesses, state-owned enterprises, financial institutions, regions, and city authorities in the efforts achieve net-zero ER actions^[40,41]. Few countries indicated that the ETF can help them improve performance in ER performance. They explained that it will help in GHG accounting and thereby, curb any dishonest tendencies of the rich to invest in activities with high GHG emissions, such as new fossil fuel supply, deforestation, and destruction of the environment. It will also help to curb the purchase of cheap credits, green-washing, impartial dealing with absolute emissions, and non-coverage of emissions across the entire business value chain.

If well integrated into the NDCs, the ETF can assist to addresses tendencies by the rich to lobby government and undermine policies that regulate trade in high-impact emission goods and services and the failure to commit to absolute to net-zero ER targets and development of appropriate instruments. Although the ETF has a wide variety of safeguard measures, its development is still in the nascent stages, which explains the limited information on the ETF under the NDCs.

Enhanced adaptation and compensation for loss and damage

Figure 13 shows progression (+23%) on proportion of information providing quality information on adaptation and loss and damage (2016: 55%; 2022: 38%). Few countries provided exclusive information on loss and damage as required by the Paris Agreement 2016. Notably, some countries indicate that the information will help them enhance their adaptive capacity, strengthen resilience, and reduce vulnerability to climate change^[42-44]. They indicated plans to undertake country-driven adaptation efforts, gender responsive, participatory, and transparency in protecting the livelihoods and integrity of vulnerable groups and ecosystems. In addition, the countries elaborated that loss and damage assessment will be based on the best available science and knowledge, including traditional knowledge, knowledge of indigenous peoples, and local knowledge systems. They expressed plans integrate adaptation into relevant socio-economic and environmental policies and actions, forge international cooperation, strengthen institutional arrangements, and enhance scientific knowledge on climate, including research, systematic observation of the climate system, and early warning systems to inform climate services and support decision-making, and develop an adaptation communication strategy. The countries also committed to identify adaptation practices, needs, priorities, support, challenges, and gaps that will help in the design and development of good national adaptation policies, plans, practices, and actions that are effective and durable. These strategies, the countries indicated would help to build the resilience of vulnerable people, places, and ecosystems.

Few countries indicate that need to address loss and damage from the adverse effects of climate change. They are linked to extreme weather events and slow-onset events. Some countries referred to the Warsaw International Mechanism in assisting to identify areas of cooperation and facilitation to enhance understanding, action, and support. Some of the suggestions for tackling loss and damage including early warning systems, emergency preparedness, slow-onset events, comprehensive risk assessment and management, risk insurance facilities, and promoting resilience of communities, livelihoods, and ecosystems.

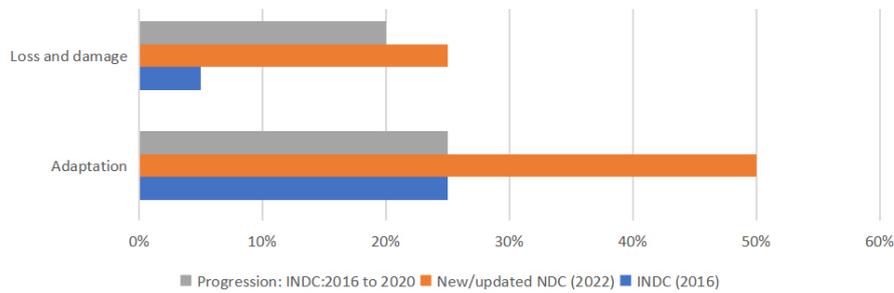


Figure 13. Information on adaptation and loss and damage.

Constructing sustainable and inclusive net-zero ER pathways

Table 7 shows the design considerations for constructing plausible sustainable and inclusive net-zero ER pathways. The design considerations are informed by results from the global aggregate analysis of the successive NDCs and organized through four steps. First, we design a template for develop sustainable and inclusive net-zero ER pathways based on the two scenarios of limiting increase in the global average temperature of 2 °C which is the less ambitious option, and 1.5 °C which is the highest ambition under the Paris Agreement.

Second, the NDCs structural elements were vertically organized including Paris Agreement Goals, net-zero ER targets, climate mitigation actions, and safeguards. Third, these elements were elaborated into indicators and further sub-indicators. Fourth, range of scores corresponding to 2 °C scenario which can be achieved under the targets, measures and safeguards with an aggregate scores ranging from 0.0% to 38.0% (low ambitious or business-as-usual pathways); 1.7 °C scenario which can be achieved under aggregate scores ranging from 39.0% to 87% (moderately ambitious or sustainable and inclusive pathway); and 1.5 °C scenario which can be achieved under aggregate scores of 86% to 100% (highly ambitious or sustainable and exclusive pathways) respectively. Fifth, the respective targets, mitigation and adaptation measures, and safeguards under each pathway are populated into the template for consideration by countries based on the national circumstances including, including the country's geographic, geopolitical, climatic, and economic growth, capacities, finances, technical skills, technology development and transfer, development aspirations, and safeguards including good governance.

CONCLUSIONS

This paper has developed and tested the ECMAS Indicator Framework with the aim of assessing the aggregate global progression towards pursuing sustainable and inclusive net-zero emission reductions pathways and subsequent outcomes by mid-century. The framework was applied to 188 successive NDCs communicated to the UNFCCC secretariat over the period 2016 to 2022. The paper draws five conclusions. First, although almost all countries have consistently communicated their NDCs to the UNFCCC secretariat, the numerous inconsistencies in the framing and setting of net-zero ER targets might compromise global progression toward achieving the Paris Agreement goals under the context of sustainable and inclusive outcomes. The successive NDCs communicated to the UNFCCC in 2016 and 2022 have failed to address these inconsistencies to harmonize ER ambitions.

Second, while most countries have demonstrated economy-wide ER by including most of the IPCC GHG sectors, there are still unmet ER ambitions at the GHGs coverage and the categories. Specifically, there is limited deepening of emissions cuts at activities level, across value chains, and within the GHG pools. There is limited coherency and consistency across NDCs on the set ER targets with respect to reference points,

Table 7. Proposed plausible sustainable and inclusive net-zero ER pathways

Information for improving clarity, transparency, and understanding of optional pathways			
Goals	Targets	Net-zero emission reduction indicators	
		Low ambition indicator pathway	High ambition pathway
Long-term global temperature	Hold increases in global average temperature Pursue efforts to limit the increase in global average temperature	2 C	1.5 °C
Net-zero ER targets	Climate neutrality Carbon neutrality GHG neutrality Net-zero emissions	2050 2060	2040 2050
Gases		CO ₂ , N ₂ O	CH ₄
Reference points			
Business as usual projected GHG emissions	2025 with base year (2019) 2030 with base year (2019)	Higher 52.4 Gt CO ₂ (4.5%) Higher 11.4 Gt CO ₂ (5%)	
NDC projected ER (2016)	2030 with base year (2019)		Lower 12.2 Gt CO ₂ (5%)
NDC projected ER (2022)	2030 with base year (2019)	Increase 11.5 Gt CO ₂ (5.0%-18.1%)	
NDC project ER (Methane)	2025 with base year (2019)		Lower Gt CO ₂ (43%-45%)
Climate mitigation efforts			
Sectors	Energy sector Agriculture Forestry Waste	Priority Priority Priority	Priority
Categories	Livestock (<i>Enteric fermentation and manure</i>) Paddy rice		Priority
Mitigation co-benefits	Economic diversification Adaptation		Priority
Safeguards	Social • Adopt the equity principle. • Targeted climate empowerment action • Include knowledge of all • Engage all in politics of development Ecological • Adopt multiple sets of eco-centric targets • Legal protection and adaptive capacity of the marginalized • Green international instruments • Rule for equitable sharing of rights, responsibility, and risks Relational • Enhanced Transparency Framework • Social movements, practice & epistemic community		Priority Priority
National circumstances	Geographic, geopolitical, climatic, economic growth, and development aspirations • Determines the setting of ER levels and the mix of climate mitigation actions		Priority

timelines, and coverage of GHGs. For example there limited coverage of short-lived climate pollutants, and radiative enforcers. The implications are the global warming and environmental pollution will continue to soar leaving marginalized communities exposed to short-lived climate pollutants and radiative enforcers, resulting in public health concerns, including heart and respiratory complications, ecosystem damage,

disruptions in the climate system, especially precipitation patterns, and food insecurity. This represent unmet progress in the ambition to deepen emission reductions with sector-specific activities, value-chain enhancements, and mitigation co-benefits from economic diversification and adaptation.

Third, although all countries demonstrate progression in establishing safeguards for marginalized sectors, places, ecosystems, and social groups, there are still gaps in elaborating social, ecological, and relational principles. Ambitions to provide information on institutional arrangements have not been fully met. The NDCs fail to provide sufficient information on the status and dynamics of social movements needed to advance climate justice. Epistemic communities and communities of practice have neither been identified, nor has their role been elaborated upon, in questioning dominant discourses that promote multiple trade-offs, favouring the rich at the cost of socio-ecological inequalities.

Fourth, aggregate analytics can aid in designing sustainable and inclusive net-zero ER pathways and subsequent outcomes. By determining the most plausible global average temperature scenarios that can safe the planet including the marginalized, targets, measures, and safeguards can be identified from aggregate analysis sustainable and inclusive net-zero ER pathways can be established and pursue to achieve the Paris Agreement goals under the context of sustainable and inclusive outcomes.

Fifth, compared to other NDCs tools, this framework systematically examines all aspects of NDCs to help countries understand the overall global aggregate progression towards the net-zero ER target and the Paris Agreement goals. It also provides countries with insights to design national sustainable and inclusive net-zero ER pathways towards achieving the Paris Agreement goals. Such pathways would replace the current practice by countries in developing a multiplicity of plans to achieve the Paris Agreement goal. It can assist to merge the NDCs with national adaptation plans, economic diversification plans, climate investment plans, and low-emission and climate-resilient plans.

RECOMMENDATIONS

This paper makes scholarly and policy recommendations concerning the sustainability and inclusiveness of Nationally Determined Contributions towards achieving the Paris Agreement goals. Firstly, for countries to progress towards achieving net-zero emission reduction targets by mid-century in a fair and ambitious manner, scholarship and policy efforts will be needed to address inconsistencies in terminologies under net-zero and limitations in ER ambitions. Secondly, for countries to collectively achieve Paris Agreement under the context of sustainable and inclusive outcomes, safeguards need to be adequately elaborated to help in tackling the potential socio-ecological inequalities under the NDC. Third, new and innovative tools for planning and tracking the implementing of the NDC are needed. This paper has developed the EC-MAS Indicator Framework which can be further improved, tested in different contexts and up-scaled to help improve the implementation effectiveness of NDC. This paper did not examine GHG emission reduction under the suggested sustainable and inclusive net-zero ER pathways. Finally, the paper did not test the tool in any specific country to determine its application and operational implications under different prevailing national circumstances. These limitations need to inform further research on the planning and implementation of sustainable and inclusive net-zero emissions reduction pathways.

DECLARATIONS

Authors' contributions

Conceptualized, undertook aggregate analysis and drafting of the manuscript: Muchemi J

Provided structural arrangements and editing: Gupta J

Provide grammatical editing: McCall M

Guided the entire process of drafting and responses to comments from the journal: Pfeffer K

Availability of data and materials

An indication that the data supporting the conclusions can be provided upon reasonable request to the corresponding author.

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All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

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