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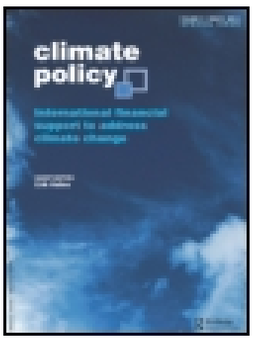

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Integration of Short-Lived Climate Pollutant and air pollutant mitigation in nationally determined contributions

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ABSTRACT

Limiting global temperature increases to 1.5 °C while respecting 'the right to health' requires substantial reductions in Short-Lived Climate Pollutants (SLCPs), including methane, black carbon and hydrofluorocarbons, and co-emitted air pollutants. This study evaluates the inclusion of SLCP and air pollutant mitigation within Nationally Determined Contributions (NDCs) that were submitted between 2015 and 2022. Between pre- and post-2020 NDCs, explicit reference to SLCPs and air pollutant mitigation as priorities more than doubled, indicating a rise in policy attention to these pollutants. There was also a large increase in the percentage of countries including methane and HFCs within the scope of their overall GHG reduction targets, and three countries include explicit black carbon reduction targets. With respect to policy, there was a 45% increase in the number of specific mitigation measures included in NDCs post-2020. Hence, the number of countries with implicit reductions in SLCPs and other air pollutants covered in their NDCs is now also substantially larger compared to pre-2020, due to greater inclusion of mitigation measures that reduce SLCPs and air pollutants alongside (other) GHGs.

Key policy insights:

- Local benefits for human health from air pollution improvements is a key priority for more countries in post-2020 NDCs compared to earlier NDC reporting.
- Many countries now include specific mitigation measures in NDCs that can simultaneously reduce SLCPs and co-emitted air pollutants alongside GHGs, helping to achieve local air quality and health improvements.
- To demonstrate the achievement of local air pollutant and SLCP reductions, countries focusing on NDC implementation should ensure air pollutants and SLCPs are integrated into climate change monitoring frameworks.
- Post-2020 NDCs provide many clear examples of how inclusion of SLCPs and air pollutants can both increase climate change mitigation ambition and achieve local development benefits, which could be adopted in other countries.

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Air pollution; climate change mitigation; climate change policies; public health

1. Introduction

Achieving the Paris Agreement's goal to limit global temperature increases below 2 °C and to aim for 1.5 °C requires that greenhouse gas (GHG) emissions are almost halved by 2030 (IPCC, 2021, 2018). Substantial reductions in Short-Lived Climate Pollutant (SLCP) emissions are also necessary. Short-Lived Climate Pollutants include methane (CH_4), hydrofluorocarbons (HFCs), black carbon (BC) and tropospheric ozone (O_3). They

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contribute to climate warming but, in contrast to carbon dioxide (CO_2), have relatively short atmospheric lifetimes (days to two decades, CCAC SNAP, 2018). Mitigation of SLCPs is therefore key to limiting near-term temperature increases, as a complement to large-scale CO_2 emission reductions (Shindell et al., 2012). IPCC (2018) identified no emission scenario limiting global temperature increases to 1.5 °C without substantial reductions in SLCPs (at least 35% reduction in methane and black carbon emissions by 2050). A 45% reduction in CH_4 emissions by 2030 is the most cost-effective pathway to limit temperature increases to 1.5 °C (UNEP CCAC, 2021).

Reducing SLCPs also links climate mitigation and human health. Short-Lived Climate Pollutants (with the exception of HFCs) are, directly or indirectly, also air pollutants, exposure to which results in negative health outcomes (Malley et al., 2017; WHO, 2021). Major sources of SLCPs often also emit other air pollutants, including particulate matter ($PM_{2.5}$), nitrogen oxides (NO_x), volatile organic compounds (VOCs), sulphur dioxide (SO_2), ammonia (NH_3) and carbon monoxide (CO), which contribute to 6.7 million air pollution-attributable premature deaths per year (IEA, 2016; Murray et al., 2020). Tackling climate change and air pollution together can yield large human health benefits with over 1 million premature deaths per year avoided from limiting global temperature increases to 2 °C (Vandyck et al., 2018).

The Paris Agreement requires Parties to submit, and update every five years, 'Nationally Determined Contributions' (NDCs) to achieve the global temperature goals. Inclusion of commitments and actions targeting SLCPs and air pollutants within NDCs can help achieve three goals. Firstly, climate mitigation ambition can be increased by reducing the climate change impact of SLCPs themselves, and by including mitigation measures that simultaneously reduce GHGs like CO_2 emitted alongside SLCPs and air pollutants (CCAC SNAP, 2019). Secondly, it provides an opportunity to increase the human health and sustainable development benefits that can be achieved from meeting climate change mitigation targets (CCAC SNAP, 2019; Haines et al., 2017). Thirdly, it can promote policy coherence between climate change mitigation and air pollution planning, and avoid tradeoffs evident when this integration has not occurred, e.g. promotion of diesel vehicles in Europe during the 2000s (Jonson et al., 2017).

The Paris Agreement, Decision 1/CP.21 and Decision 3/CMA.1 outline information that Parties agree to submit to facilitate 'clarity, transparency and understanding' of NDCs (United Nations, 2015). However, the inclusion of SLCPs and other air pollutants is not required. As a result, some NDCs include SLCPs such as methane and HFCs within overall GHG reduction targets, which makes understanding the implied level of reduction in these SLCPs difficult. Other NDCs do not include or refer to SLCPs or other air pollutants, but do include mitigation measures that target major SLCP and air pollutant emission sources. For GHGs, studies have compiled and synthesized the NDC commitments, and their effectiveness at reducing GHG emissions (UNFCCC Secretariat, 2021). However, there has not been a comparable assessment of the inclusion of SLCP and other air pollutant mitigation within NDCs that assesses explicit and implicit inclusion of SLCP and other air pollutant reductions.

The first updating of NDCs in advance of the 26th Conference of the Parties (COP26) provides an opportunity for a comparative assessment on the progress made in the integration of SLCP and air pollutant mitigation within climate change planning. This assessment aims to answer the following questions:

- To what extent are the current NDCs aiming to achieve large-scale SLCP and air pollution emission reductions, alongside ambitious GHG reductions?
- How has the potential of NDCs to reduce SLCPs and air pollutant emissions alongside GHGs changed between NDCs submitted before and after 2020?

This study explores these questions through the application of a framework, described in Section 2, that assesses multiple components of NDCs that indicate the level of SLCP and air pollution emission reductions, and human health benefits, that could be achieved from their implementation. These components include language on SLCPs, air pollution and health (Section 3.1), specific, quantitative targets included in the NDC (Section 3.2), and explicit mitigation measures outlined to achieve targets and commitments (Section 3.3). Finally, Section 4 discusses the implications for climate change planning and air quality management of the extent of inclusion of SLCP and air pollution mitigation in NDCs is discussed, and compared the application of this framework to assess the inclusion of air pollution and other development priorities in NDCs with previous evaluations.

2. Methods

2.1 Documents and reports included in the analysis

All NDCs submitted as of July 2022 were extracted from the United National Framework Convention on Climate Change NDC Registry (https://unfccc.int/ndcreg). NDCs were separated into those submitted before 2020 ('pre-2020 NDCs') and those submitted in, or after, 2020 ('post-2020'). This separation reflects that the majority of countries submitted their first NDC between 2015 and 2018, and then, in advance of COP26, submitted updated NDCs in 2020-2022. Where a country submitted multiple NDC updates before or after 2020, the most recent was used in both cases. In total, the pre- and post-2020 groups included 159 submissions (15 Annex 1, 144 Non-Annex 1), and 167 submissions (18 Annex 1, 149 Non-Annex 1), respectively. The latter group includes the submissions from 32 countries that submitted NDCs before 2020, and have not yet submitted an update. Based on national GHG and SLCP emissions estimated for 2018 (most recent year available) by the Emissions Database for Global Atmospheric Research (EDGAR, Crippa et al., 2021), the countries whose NDCs are analysed in the pre- and post-2020 groups emit 86% and 94% of global CO_2 emissions, 89% and 98% of global CH_4 emissions, and 91% and 94% of global BC emissions, respectively.

NDCs differ in terms of style, length, content and detail. Where an NDC included all information necessary for the assessment, it was the only document reviewed. Where a specific document was referenced for further details of particular aspects relevant to the framework outlined below, these documents were also analysed. Of the 294 pre- and post-2020 NDCs reviewed, 63 (21%) included assessment of additional documents referenced within the NDC.

2.2 Framework for assessment of integration of Short-Lived Climate Pollutant and air pollution into NDCs

CCAC SNAP (2019) outlined four 'opportunities' for how SLCPs and air pollutants could be integrated into NDCs, which encompass (i) including measures to reduce methane and HFC emissions, (ii) including measures that target major sources of black carbon, (iii) including measures that reduce CO_2 and simultaneously reduce air pollutant emissions, and (iv) aligning NDCs with other plans and strategies relevant for SLCP and air pollutant mitigation. Here CCAC SNAP (2019) was used *ex-post* to evaluate the specific ways in which SLCP and air pollutant emission reductions have been included in the 294 NDCs assessed in a consistent way (Table S1 in Supplementary Material 1 summarises the components of the framework)

Firstly, the framework extracts the type, level and format of a quantitative GHG reduction target, and any specific information on how the target will be achieved. This assesses the inclusion of SLCPs like CH_4 and HFCs in GHG reduction targets. It also shows the extent to which NDCs that are more ambitious on SLCP and air pollution mitigation also have the most ambitious GHG reduction targets.

Secondly, specific language related to SLCPs, air pollution and health are identified to understand whether the NDC acknowledges the link between air pollution and climate change, and/or opportunities from action on SLCPs. Thirdly, the framework also assesses the extent to which the NDC has set targets (on BC, CH_4 or HFCs) that reduce SLCPs and air pollutants, corresponding to Opportunities 1–3 in CCAC SNAP (2019) (Table S1). This includes pollutant-specific targets, and inclusion of SLCPs within overall GHG reduction targets.

Finally, the framework identifies specific mitigation measures included to implement climate change mitigation targets. This identifies the specificity with which targets to reduce SLCPs have been defined, and whether there is a clear set of actions included to implement them. In addition, Opportunity 3 in CCAC SNAP (2019) is the inclusion of actions to reduce CO_2 that have air pollution benefits. Assessing the mitigation measures included in NDCs identifies those that include actions that could reduce air pollution and SLCPs alongside CO_2, regardless of intention, or whether these SLCP and air pollution reductions are explicitly stated. Fifty categories of mitigation measures were defined across the Energy, Industrial Processes and Product Use, Agriculture, Forestry and Land Use and Waste sectors (Table S2 in Supplementary Material 1), based on mitigation measures identified previously as effective in reducing SLCPs, air pollutants and GHGs (UNEP/WMO, 2011; UNEP, 2019, 2018; UNEP CCAC, 2021).

Together, the framework identifies the extent to which NDCs that acknowledge air pollution and SLCPs as priorities also outline appropriate targets and actions to reflect this prioritisation. It also highlights those NDCs that acknowledge the importance of SLCPs and air pollution mitigation, but where actions to increase SLCP and air pollution reductions could be enhanced. Many actions that are taken to achieve climate change commitments may also simultaneously reduce SLCPs and air pollutants without having intentionally been included in NDCs for this purpose. The framework can also identify those NDCs that have not specifically focused on SLCP and air pollutant reductions, but through their implementation could mitigation them.

3. Results

3.1 Air pollution and Short-Lived Climate Pollutant framing

The acknowledgment of the importance of SLCPs and/or air pollutant reductions more than doubled between pre-2020 and post-2020 NDCs (Table 1). For SLCPs, 16 and 47 countries acknowledged the importance of action in pre and post-2020 NDCs, respectively. More countries acknowledge the opportunity for air pollution mitigation with 36 and 65 countries in pre- and post-2020 NDCs. Five broad acknowledgement types were identified. The first was a general statement of the link between SLCP and/or air pollution mitigation and climate change, without reference to specific pollutants, sectors or mitigation options. This acknowledgement type more frequently referred to air pollution than SLCPs, and increased substantially between the pre- and post-2020 NDCs. These acknowledgments shows that the country sees the opportunity and potential for air pollution and/or SLCP reductions. However, its limitation is that it is generally not combined with specific actions to operationalise it, or an overview of the extent to which SLCP and/or air pollutant emissions will be mitigated.

The second acknowledgement type is countries specifically highlighting air pollution and/or SLCP mitigation as being a co-benefit of NDC implementation. In this case, countries are often more explicit in the actions and mitigation measures included in their NDC which could achieve air pollution and/or SLCP mitigation co-benefits alongside GHG reductions. This is the most common acknowledgment included within both pre- and post-2020 NDCs. It is more specific than a general acknowledgement, but the statements of co-benefits are unquantified and often incomplete. For example, some NDCs acknowledge air pollution co-benefits from particular actions identified as being part of implementing their NDCs, but do not acknowledge the air pollution co-benefits of other mitigation measures that are also effective at achieving this. This therefore underestimates the totality of air quality and health improvements that could be achieved from their NDC implementation.

Air pollutants and SLCPs encompass multiple individual atmospheric constituents. The third acknowledgement type is the identification of a subset of SLCPs and/or air pollutants as mitigation priorities. In post-2020 NDCs, this was most commonly specific acknowledgment of HFCs and commitment to their phasedown through the Kigali Amendment to the Montreal Protocol. Fewer NDCs use this acknowledgement type to highlight BC or CH_4 as priorities for mitigation. For air pollutants, only China and St. Lucia specifically highlight VOCs as a priority.

The most specific, but least commonly identified acknowledgement types were those that either (i) referenced a national plan, strategy, policy and/or law underpinning action on SLCPs or air pollutants, and their inclusion in the NDC, or (ii) provided quantitative information on SLCP and/or air pollution mitigation (Table 1). These acknowledgements are the most substantive as the underlying plans and policies referenced contain specific actions to reduce SLCPs and air pollutants, or because an assessment process has been undertaken to determine quantitative air pollutant and SLCP emission reductions. Countries such as Bangladesh (Bangladesh Department of Environment, 2018), Togo (Togo Ministry of Environment, 2020), Côte d'Ivoire (Cote d'Ivoire Ministry of Environment, 2019) and Nigeria (Nigeria Federal Ministry of Environment, 2019) have national action plans/strategies to reduce SLCPs. The NDC submissions for these countries explicitly acknowledge the implementation of these plans as a component of achieving their NDC.

In pre-2020 NDCs only Mexico included a quantitative BC reduction target (51% reduction in 2030 compared to baseline), while Uruguay included specific methane reduction targets (Table 1). Post-2020, 20 NDCs included quantitative information on SLCP and/or air pollutant reductions (Table 1). The majority stated specific SLCP and/or air pollutant emission reductions from implementation of the NDC, a subset of which included these

Table 1. List of countries acknowledging importance of SLCPs and air pollution mitigation in NDCs, separated by type of acknowledgement.

	General acknowledgement of link between SLCP/air pollution and climate change mitigation/ adaptation only	Reduction in SLCPs or air pollution identified as co-benefit of climate mitigation action	Specific statement on SLCPs/air pollutants emission reductions of importance	Reference to National Plan/ Strategy, Policy or regulation underpinning action on SLCPs/ air pollution	Reference includes quantitative information on SLCP/ air pollutant emission reductions and/or health benefits of NDC implementation
Pre-2020 NDC SLCP/ air pollution acknowledgement	**SLCPs** Mauritius, Central African Republic, Cote d'Ivoire **Air pollution** Benin, France (Overseas Territories), Nepal, Republic of Congo, Timor-Leste*, Uruguay*, Venezuela, Zimbabwe	**SLCPs** Nigeria **Air pollution** Angola, Bangladesh, Belize, Burkina Faso, Cameroon, Ethiopia, Jordan, Laos, Liberia, Mongolia, Myanmar, Nepal, Nigeria, Palestine, Sierra Leone, Sri Lanka, Thailand, Zambia, Comoros, Djibouti*, Ghana, India*, Lesotho*, Niue*, Syrian Arab Republic*, Trinidad and Tobago*, Uganda*	**SLCPs** Methane: Algeria*, Azerbaijan*, Cameroon, Dominica*, Ecuador*, Equatorial Guinea*, Guatemala*, Nigeria Black Carbon: Canada, Chile, Nigeria HFCs: Ghana, Nigeria	**Air pollution** Chile, Ecuador*	**SLCPs** Mexico, Uruguay*
Post-2020 NDC SLCP/ air pollution acknowledgement	**SLCPs** Eswatini, Jordan, Liberia, Pakistan, United States **Air pollution** Angola, Brunei, Cape Verde, Colombia, Cuba, Democratic Republic of Congo, Eswatini, Georgia, Maldives, Mexico, Morocco, Panama, Qatar, Republic of Congo, Tunisia, United Arab Emirates, Vietnam	**SLCPs** Dominica **Air pollution** Burkina Faso, Burundi, Cambodia, China, Dominican Republic, El Salvador, Guinea, Honduras, Iraq, Jamaica, Jordan, Laos, Lebanon, Malawi, Marshall Islands, Montenegro, Myanmar, Namibia, Nepal, North Macedonia, Oman, Pakistan, Palestine, Papua New Guinea, Paraguay, Rwanda, Senegal, Sierra Leone, South Africa, South Sudan, Sri Lanka, Tunisia, Venezuela	**SLCPs** Methane: Burkina Faso, Iraq, United States, China, Saudi Arabia, Republic of Korea, Black Carbon: Canada HFCs: Albania, Argentina, Barbados, Bhutan, Canada, China, European Union, Mauritius, Morocco, Namibia, New Zealand, Nicaragua, Pakistan, Paraguay, Sierra Leone, St. Lucia, Tunisia, United Kingdom, United States, Venezuela **Air pollution** Volatile Organic Compounds: China, St. Lucia	**SLCPs** Bangladesh, Colombia, Nigeria, Togo, Cote d'Ivoire **Air pollution** Albania, Belarus, Kuwait, Nauru, Togo, United Kingdom, Uzbekistan	**SLCPs** Bangladesh, Belize, Benin, Central African Republic, Chile, Colombia, Costa Rica, Cote d'Ivoire, Dominican Republic, Ghana, Japan, Mali, Mexico, New Zealand, Nigeria, Seychelles, Togo, Zimbabwe **Air pollution** Benin, Central African Republic, Cote d'Ivoire, Ghana, Mali, Nigeria, Togo, United States of America, Zimbabwe

*NDC submitted before 2020 that remain the country's most up to date NDC (i.e. are also included in the post-2020 NDC category).

reductions as specific mitigation targets (Section 3.2). These quantitative SLCP and air pollutant emission reduction statements also provide clarity on how individual GHGs (including CH_4 and HFCs) will be reduced to achieve the overall GHG reduction target. This is important given the different timescales and impacts of different climate forcers, and therefore provides a greater understanding of the overall climate change mitigation impact of a particular NDC. For example, Togo's NDC includes a ~50% reduction in GHG emissions by 2030 compared to a baseline scenario, but also states the reductions in individual constituents, including CH_4 (32% reduction) and HFCs (9%) (Togolese Republic, 2021).

Finally, in addition to quantitative emission reductions, post-2020 NDCs were submitted including quantitative human health benefits achievable from NDC implementation. Nigeria, Ghana and Cote d'Ivoire's NDCs state that 30,000, 2,900 and 7,000 premature deaths, respectively, could be avoided every year by 2030 due to the air pollution reductions achieved alongside GHG reduction targets (Federal Republic of Nigeria, 2021; Republic of Ghana, 2021). The United States' 2021 NDC states that its climate change actions could avoid 'tens of thousands of premature deaths' due to air pollution reductions (United States of America, 2021). Pre-2020, there were no examples of quantitative acknowledgements, such as the reduction in air pollutants, or resultant benefits for human health, that could be achieved from the implementation of the NDC (Table 1).

3.2 Quantitative targets to reduce Short-Lived Climate Pollutants

Methane and HFCs are both SLCPs and GHGs. The number of countries including CH_4 and HFCs within the scope of their GHG reduction targets increased between pre- and post-2020 NDCs. In pre-2020 NDCs, the majority (79%) included CH4, while only 28% included HFCs. Post-2020, 87% and 47% included CH_4 and HFCs, respectively. This increase is important because the contribution of reducing these SLCPs to overall GHG reduction targets can be evaluated, and their reduction contribute towards the GHG reduction target. However, their inclusion does not guarantee that the overall GHG reduction target will be achieved by reducing CH_4 and HFC emissions. Few countries provide additional clarity by including specific CH_4 or HFC targets. Belize, Japan, New Zealand, Seychelles, and Uruguay are the only countries to have set specific methane reduction targets within its NDC (Supplementary Material 2). Japan outlines that to achieve its 46% overall GHG reduction target, methane emissions will be 26.7 million tonnes CO_2-eq in 2030, compared to 30 million tonnes CO_2-eq in 2013 (Japan, 2021). For Uruguay, an economy-wide methane emission intensity target is set (57% reduction in CH_4 per unit of GDP), as well as livestock CH_4-specific targets (32% reduction in CH_4 emissions per kg beef cattle) (Oriental Republic of Uruguay, 2017). Belize and New Zealand similarly set livestock-specific methane reduction targets, while the Seychelles set a methane reduction target in the waste sector (Belize, 2021; New Zealand, 2021; Republic of Seychelles, 2021). For HFCs, Japan outlines that in 2030 there will be 21.8 million tonnes CO_2-eq emissions, compared to 39.1 million tonnes in 2013. No other countries outline specific HFC reduction targets, but many identify implementation of the Kigali Amendment as the key mitigation action to reduce HFCs (see Section 3.3). This provides clarity on how HFC reductions contribute to overall GHG mitigation targets, because of the HFC consumption-based reduction targets included in the Kigali Amendment (United Nations, 2016).

Black carbon is an SLCP, but not a GHG, and therefore not covered in the scope of GHG reduction targets. Several NDCs have defined separate targets to reduce black carbon emissions, including Mexico in pre-2020 NDCs. Post-2020, three NDCs set quantitative black carbon emission targets including, Colombia (40% reduction in BC emissions in 2030 compared to 2014 levels), and Chile (25% reduction in BC emissions in 2030 compared to 2016 levels) in addition to Mexico (Government of Chile, 2020; Government of Colombia, 2020; Government of Mexico, 2020). Several additional countries submitted post-2020 NDCs that outlined the expected black carbon (and other air pollutants) emission reductions that could be achieved from implementation of their NDCs, but stopped short of committing to these reductions as formal targets (Section 3.1, Table 1).

3.3 Mitigation measures with short-lived climate pollutant and air pollutant reduction potential

Assessment of the GHG mitigation measures identified in NDCs to achieve mitigation commitments highlights the extent to which pre- and post-2020 NDCs contain actions, explicitly and implicitly, that will reduce SLCPs

and air pollutants. Table S2 shows the number of pre and post-2020 NDCs which included specific mitigation measures that could reduce SLCPs and air pollutants alongside GHGs. The assessment of individual NDCs used to produce Table S2 are included in Supplementary Material 2. The total number of mitigation measures specified in NDCs in the 50 groups used in this assessment increased by 45%, from 1580 to 2293 in pre- and post-2020 NDCs, respectively. This emphasises that NDCs are becoming increasingly specific about the mitigation measures underpinning mitigation targets and is reflected in mitigation measures across almost all major SLCP and air pollutant-emitting source sectors (Table S2), and across geographic regions (Figure 1).

For some SLCP and air pollutant emitting source sectors, the type of mitigation measures also shifted. For example, in transport, the most common mitigation measure in pre-2020 NDCs was increased public and active transport, and vehicle fuel efficiency (Table S2, Figure 1). The number of NDCs including these options increased but there was a substantially larger increase for electromobility, from 20% of pre-2020 NDCs to 52% post-2020, making it the most common transport mitigation measure. This illustrates the importance of identifying specific mitigation measures to understand the consequences of NDC implementation on air pollution and SLCPs. Mitigation measures have different effectiveness at reducing air pollutants and SLCPs alongside GHGs. Electric vehicles result in zero exhaust emissions, making it particularly effective for reducing air pollutant emissions alongside reducing CO_2. In contrast, increasing the efficiency of vehicles can be effective at reducing fuel consumption, and CO_2 emissions, but does not necessarily reduce air pollutant emissions because this depends on the vehicle emission control technology (e.g. Euro standards). The increase in inclusion of electromobility within NDCs is therefore positive for achieving air pollution benefits alongside GHG reductions in transport.

In the residential and commercial sectors, the number of countries including key black carbon (and other air pollutant) mitigation measures, such as switching to clean air fuels, or more efficient biomass stoves, for cooking and heating increased from pre- to post-2020 NDCs. African countries most commonly included these measures in their NDCs (Figure 1), consistent with the largest prevalence of cooking using solid biomass occurring in Africa. However, a substantial fraction of households in Latin America and Asia also use biomass stoves for cooking, which contributes to the substantial health burden from air pollution indoors and outdoors (Stoner et al., 2021). In these regions less than 20% of NDC submissions included mitigation measures on residential cooking, and there was not a substantial increase between pre- and post-2020.

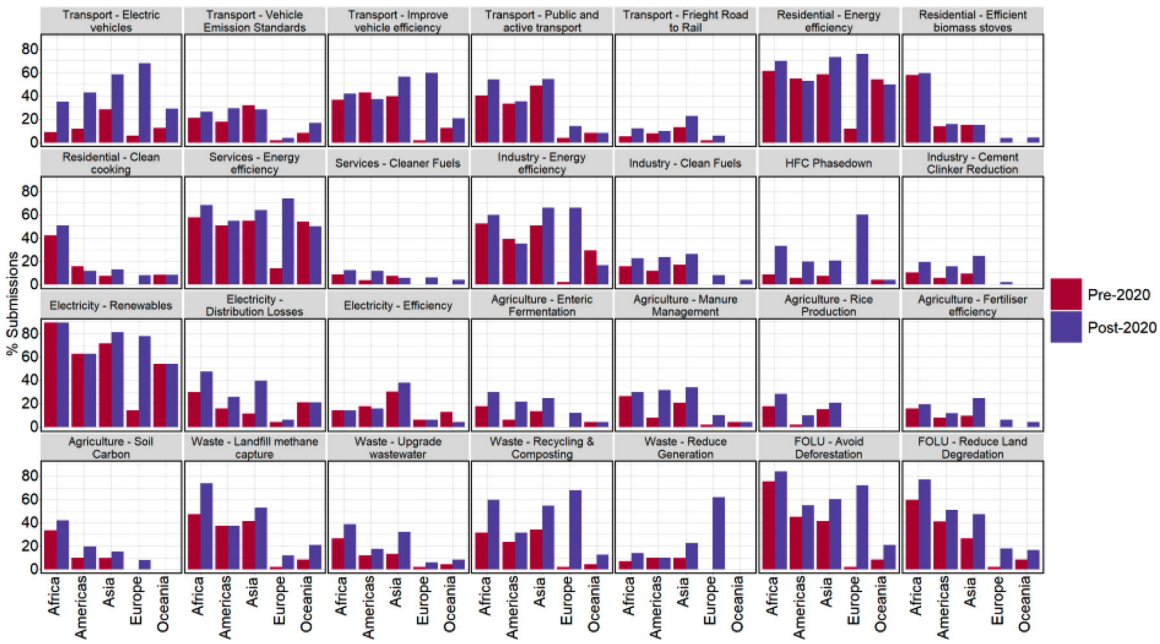

Figure 1. Percent of submissions from UN regions in pre-2020 and post-2020 NDCs that included specific mitigation measures (note: in this figure the submission of European Union is considered as 27 submissions for each EU Member State).

In industry, only 8% of countries included HFC mitigation in pre-2020 NDCs, compared to 27% post-2020 (Figure 1), the majority reflecting the Kigali Amendment to the Montreal Protocol (United Nations, 2016). In oil and gas, relatively few countries identified any measures to reduce SLCPs (including black carbon from flaring, or fugitive methane), with the most common measure reducing fugitive methane, included in 17% of post-2020 NDCs. Only one country (Costa Rica) specifically included measures to limit oil and gas production, despite being necessary to limit global temperature increases to 1.5 ^{o}C (SEI et al., 2021).

In agriculture, fewer NDCs included SLCP and air pollutant-focused mitigation measures than in the energy sector, e.g. methane reductions from livestock enteric fermentation, manure management and rice production, or reducing open burning of crop residues (Table S1, Figure 1). Despite this, the number of NDCs including agricultural measures increased substantially pre- and post-2020. The number of NDCs including measures on livestock enteric fermentation more than doubled between pre- and post-2020, and almost doubled for measures on manure management and rice production (Figure 1, Table S2). Other measures also increased in NDCs in the agriculture sector, including reducing crop residue burning, and more efficient fertiliser use (Table S2). These measures could not only reduce SLCPs like black carbon and methane, but could also reduce emissions of air pollutants such as ammonia, which makes a substantial contribution to secondary particulate matter (Fuzzi et al., 2015). An even smaller fraction of NDCs included off-farm mitigation measures to reduce emissions within their NDCs, but their inclusion increased post-2020. For example, reducing food waste was included in eight NDCs post-2020, but zero pre-2020 NDCs, while shifting diets to food products with lower embedded GHG emissions (including methane) remains almost absent. Reducing forest fires is a key measure to improve air quality, and is included in only 13% of post-2020 NDCs (Table S2).

Finally, in the waste sector, there were substantially more NDCs identifying measures to reduce emissions from solid waste generation compared to liquid waste, despite the latter making a larger contribution to GHG emissions (Crippa et al., 2021). Post-2020, 61% of NDCs include measures to reduce methane emissions from landfill sites. By contrast, only 34% of post-2020 NDCs included reducing methane from wastewater treatment plants.

4. Discussion

4.1 Comparison with previous NDC assessments

The framework used here differs from previous assessments, as well as frameworks that have assessed the inclusion of other co-benefits. Firstly, this framework identifies both those NDCs which explicitly include SLCPs and air pollutants, and where reductions in SLCPs and air pollutants are implicit in the measures outlined to achieve the NDC. While an increasing number of countries explicitly acknowledge the importance of SLCPs and co-emitted air pollutants in post-2020 NDCs compared to pre-2020 NDCs, it is still a small minority. However, this study shows a 45% increase in the number of specific mitigation measures included in NDCs post-2020, indicating that a substantially larger number of NDCs now implicitly include potential SLCP and air pollutant reductions.

These results complement other approaches for evaluating NDCs. The UNFCCC Secretariat analyses all NDCs in 'Synthesis Reports' so as to evaluate the combined GHG reduction outcomes, and other aspects such as what mitigation measures are identified to implement the GHG reduction targets. The latest Synthesis Report states that only 7% of NDCs cover 'SLCPs'; yet for specific SLCPs, 87% of NDCs are stated to cover CH_4, and 48% HFCs (UNFCCC, 2021). These results are consistent with the percentage of NDCs identified here as including CH_4 and HFCs in the scope of their GHG reduction target. Importantly, this assessment shows that, while only a small number of countries explicitly include the term 'Short-Lived Climate Pollutants' in their NDCs, a substantially larger number of countries include mitigation measures that would be effective in reducing BC from major sources as well as reductions in other SLCPs and air pollutants. Therefore, the conclusion of limited SLCP coverage in NDCs by UNFCCC (2021) underestimates the policy attention to these pollutants.

Finally, multiple studies have assessed different aspects of sustainable development and human health issues included within NDCs and the results of this study complements these, focusing in particular on air pollutant mitigation and health. This includes UNFCCC (2021) that notes that multiple NDCs include SDG benefits

within their submissions. The 'NDC Explorer' identifies those NDCs which 'mention' one or multiple sustainable development goals (Pauw et al., 2016, 2018). The NDC-SDG connections tool identifies the extent to which actions included in NDCs (submitted before 2020) help to achieve different SDG targets (Dzebo et al., 2017). The Global Climate and Health Alliance's 'Healthy NDC scoring system' awards points for the integration of 'health' in NDCs. For climate mitigation and health integration, points are awarded only where mitigation measures identified in NDCs specifically stated that these measures would lead to health benefits; it does not however score based on an evaluation of whether specific mitigation measures would actually achieve health benefits, e.g. through air pollution emission reductions (GCHA, 2021). The Lancet Countdown on Climate and Health reports on the representation of health within NDCs, alongside other intersections between climate change and human health. The 2021 report notes that the number of countries referencing health increased from 56% of NDCs submitted between 2015 and 2016, to 91% of NDCs submitted as of 2021. However, the disaggregation of health issues is limited, i.e. air pollution and its health impacts is not distinguished from other health aspects included in NDCs, and implicit health improvements from climate change actions are not covered (Romanello et al., 2021).

The assessment of explicit and implicit inclusion of potential air pollution reductions within NDCs provides more detail than previous assessments on the representation of this particular development priority within NDCs. For example, the UNFCCC Synthesis Report and the NDC Explorer do not identify the specific SDGs or related actions could achieve. The NDC-SDG connections tool, a link to the SDG targets covering air pollution is made for those NDCs that include actions to reduce air pollution. For example, Nigeria's 2015 NDC includes actions that will improve air quality (Government of Nigeria, 2015), and the NDC-SDG connections tool links to SDG 3.4 'Reduce mortality from non-communicable diseases'. However, the specific actions included within the NDC are not sufficiently specified, so it is unclear what aspects of the NDC relate to air pollution and relevant SDGs. The Climate Watch Platform (https://www.climatewatchdata.org/) extracts similar data from NDCs as this study, including those mitigation measures identified within NDCs to achieve climate change mitigation targets. However, it does not synthesise this information to identify the multiple approaches to integration of SLCPs and air pollutants reflected in NDCs, nor assess documents referenced by NDCs as containing the information on how climate change mitigation actions will be achieved.

The identification of mitigation measures included within NDCs also highlights that for some sectors, the mitigation measures specified, are more effective at reducing SLCP and air pollutant emissions alongside GHGs, compared to others. For example, in the transport sector, the identification that 52% of post-2020 NDCs include electromobility shows that this sector can achieve substantial co-benefits for air pollution and human health; switching to electric vehicles reduces CO_2 emissions, while simultaneously reducing black carbon exhaust emissions and other air pollutants. Only by identifying the specific mitigation measures included within NDCs can an assessment be made of the extent to which these measures, and hence the NDC overall, can contribute to reducing GHG, SLCP and air pollutant emissions.

4.2 Implications for climate change and air pollution mitigation

This assessment deliberately considers only the integration of SLCPs and air pollutant mitigation alongside GHG mitigation within NDCs, and does not review the totality of planning and policy making processes within countries relevant for SLCP and air pollution mitigation. For example, 46 countries included HFC mitigation in their NDCs, but more than double (95) have ratified the Kigali Amendment. Similarly, this study identifies that 31% of NDCs (52 submissions) include vehicle emission standards, while 100 countries have vehicle emission standards in place (UNEP, 2021).

The relevance of assessing the inclusion of SLCP and air pollutant-targeted actions in NDCs only, as opposed to their general adoption, is that firstly it demonstrates that SLCP and/or air pollution actions contribute to achieving national climate change mitigation commitments. Secondly, it demonstrates that the achievement of climate change commitments can result in local benefits for human health which can build a broader coalition of support for implementation (Linnér et al., 2012; Malley et al., 2021). Finally, it contributes to increasing consistency between air pollution and climate change planning, and avoiding tradeoffs that have previously occurred when air pollution impacts of climate change plans were not considered, e.g. the promotion of

diesel vehicles in Europe in the 2000s for climate change mitigation, which exacerbated air pollution across Europe (Jonson et al., 2017).

This assessment highlights that the enhancement in global climate change mitigation ambition between pre-2020 and post-2020 NDCs has been achieved, in part, through inclusion of mitigation measures that reduce SLCPs. Specifically, a substantially larger number of countries have reflected measures that will lead to additional CH_4 and HFC emission reductions if fully implemented.

Going forward, this analysis also shows the substantial potential to increase SLCP emission reductions to contribute to more ambitious global climate change mitigation targets, consistent with the Glasgow Climate Pact that invites countries to increase climate change mitigation ambitions through actions to reduce non-CO_2 GHGs, like methane (United Nations, 2021). Furthermore, the Global Methane Pledge commits participating countries to collaborate towards reducing global CH_4 emissions by 30% by 2030 compared to 2020 levels but does not specify national targets or actions to achieve this. This analysis shows that a minority of countries included actions in the three major anthropogenic CH4 emitting source sectors (fossil fuel production, agriculture and waste) to reduce CH4 in their post-2020 NDCs. However, most NDCs evaluated were submitted before the establishment of the Global Methane Pledge; and since its establishment, only the United States has developed a national CH_4 emission reduction action plan, which includes mitigation measures identified in their 2021 NDC update described in greater detail (White House Office of Domestic Climate Policy, 2021). Similarly, fewer post-2020 NDCs include HFC mitigation than countries that have ratified the Kigali Amendment. Therefore, a focus on identifying and evaluating specific mitigation measures on SLCPs such as methane and HFCs could provide the basis for more ambitious future NDC updates.

With respect to the intersection with health policy goals, previous studies highlight the significant potential additional benefits from raising climate change mitigation ambition for local development (Linnér et al., 2012; Malley et al., 2021). Millions of premature deaths can be avoided annually through reductions in air pollution achieved from implementation of climate change mitigation plans (UNEP/WMO, 2011; UNEP, 2019; Vandyck et al., 2018). This assessment's focus on the explicit acknowledgement and implicit inclusion of air pollutant mitigation in NDCs clearly indicates the extent to which the opportunity to improve air quality through climate action is recognized by governments. It shows that more countries are prioritising air pollution and human health as part of their climate change strategies, as reported in their NDCs. Even more significantly for achieving health benefits are the greater number of mitigation measures included in post-2020 NDCs targeting reduction of SLCP and air pollutant emissions compared to pre-2020. Fully implementing these could improve air quality and benefit public health locally, demonstrating the value of climate change mitigation actions to a country's own local development priorities.

However, a gap remains between the opportunity to achieve air pollution and human health benefits from climate change action, and the extent to which countries have collectively reflected this opportunity in NDCs. For example, only a minority of countries explicitly include action on residential biomass burning for cooking within their post-2020 NDCs (Table S2, Figure 1). As a top 10 global risk factor for human health (Murray et al., 2020), and given links to both SLCP and GHG emissions during cooking, as well as to deforestation and land degradation from wood consumption, argues for substantially more attention to be given to clean cooking in future NDC updates. There are similar opportunities in other sectors, most notably in agriculture (reducing crop residue burning), and waste (improving waste collected and best practice landfill management), while in other sectors substantial progress has been made in the inclusion of measures with the largest SLCP and air pollution emission reduction potential (e.g. transport (electric vehicle, public and active travel)).

It is in the interest of all countries to submit enhanced NDCs which contain additional, specific mitigation measures that target major SLCP and air pollution sources, because the benefits to human health, crop production and the environment from reducing air pollution are disproportionally achieved locally (Shindell et al., 2012). Actions on SLCPs and air pollutants also have economic benefits, and can help to achieve a range of other sustainable development goals (Haines et al., 2017). To demonstrate that these local benefits of climate action are being achieved, and assess the effectiveness of NDC implementation on local air pollution and public health, it is recommended that SLCP and air pollutant emissions are integrated into the monitoring and reporting frameworks used to track progress on NDC implementation. Practical examples and guidance for such integration of monitoring frameworks are readily available (CCAC SNAP, 2019, 2018).

5. Conclusions and recommendations

This assessment has shown that the first major update of most Nationally Determined Contributions has resulted in a substantially larger number of countries explicitly acknowledging the importance of reducing Short-Lived Climate Pollutant, and air pollutant emissions, and improving public health, while achieving their climate change mitigation targets. It also shows that because of the mitigation measures identified in post-2020 NDCs to achieve climate change mitigation targets, an even larger number of countries will reduce their SLCP and air pollutant emissions from NDC implemented, compared to pre-2020, even if this is not explicitly acknowledged within the NDC. As post-2020 NDCs begin implementation, ensuring that these SLCP and air pollutant emission reductions, and public health benefits are monitored alongside progress towards climate change mitigation targets is an important step to demonstrate the effectiveness of NDCs in achieving local development goals. Finally, despite progress between 2015 and 2022, a large number of countries do not yet include or prioritise SLCP and/or air pollution mitigation within NDCs, meaning that an increased focus on SLCP and air pollutant mitigation actions could increase climate change mitigation ambition in future NDC updates. Specifically, 49 countries that have ratified the Kigali Amendment have not reflected this contribution to climate change mitigation in their NDCs. In addition, a minority of countries include actions to mitigate methane within post-2020 NDCs, and therefore to achieve international methane reduction goals, countries should consider updating NDCs with enhanced methane mitigation ambition.

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References

Bangladesh Department of Environment. (2018). Bangladesh National Action Plan for Reducing Short-Lived Climate Pollutants. Department of Environment, Ministry of Environment, Forests and Climate Change Report. June 2018. Available at: https://www.ccacoalition.org/en/resources/bangladesh-national-acti

Belize. (2021). Updated Nationally Determined Contribution. Belize submission to the United Nations Framework Convention on Climate Change. Available at: https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party = BLZ

CCAC SNAP. (2018). Guidance for national planning to reduce short-lived climate pollutants. Climate and Clean Air Coalition Supporting National Action & Planning on Short-Lived Climate Pollutant Mitigation Initiative report. Available at: https://ccacoalition.org/ar/resourc

CCAC SNAP. (2019). Opportunities for Increasing Ambition of Nationally Determined Contributions through Integrated Air Pollution and Climate Change Planning: A Practical Guidance document. Climate and Clean Air Coalition Supporting National Action & Planning Initiative Repo.

Cote d'Ivoire Ministry of Environment. (2019). Cote d'Ivoire National SLCP Action Plan. Cote d'Ivoire Ministry of Environment. Available at: https://ccacoalition.org/en/resources/summary-cote-divoire-national-slcp-action-plan

Crippa, M., Guizzardi, D., Solazzo, E., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Banja, M., Olivier, J. G. J., Grassi, G., Rossi, S., & Vignati, E. (2021). GHG emissions of all world countries - 2021 Report, EUR 30831 EN, Publications Office of the European Union, Luxembourg, 2021, doi:10.2760/173513JRC126363.

Dzebo, A., Brandi, C., Janetschek, H., Savvidou, G., Adams, K., & Chan, S. (2017). Exploring connections between the Paris Agreement and the 2030 Agenda for Sustainable Development. SEI Policy Brief.

Federal Republic of Nigeria. (2021). Nigeria's Nationally Determined Contribution. Federal Republic of Nigeria submission to the United Nations Framework Convention on Climate Change. Available at: https://www4.unfccc.int/sites/ndcstaging/Pages/Party.aspx?party = NGA&prototype = 1

Fuzzi, S., Baltensperger, U., Carslaw, K., Decesari, S., Denier Van Der Gon, H., Facchini, M. C., Fowler, D., Koren, I., Langford, B., Lohmann, U., Nemitz, E., Pandis, S., Riipinen, I., Rudich, Y., Schaap, M., Slowik, J. G., Spracklen, D. V., Vignati, E., Wild, M., … Gilardoni, S. (2015). Particulate matter, air quality and climate: Lessons learned and future needs. *Atmospheric Chemistry and Physics*, 15, 8217–8299. https://doi.org/10.5194/acp-15-8217-2015

GCHA. (2021). GCHA Health NDCs Scorecard. Global Climate and Health Alliance. Available at: https://climateandhealthalliance.org/initiatives/healthy-ndcs/ndc-scorecards/

Government of Chile. (2020). Chile's Nationally Determined Contribution. Government of Chile submission to the United Nations Framework Convention on Climate Change. Available at: https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party = CHL

Government of Colombia. (2020). Nationally Determined Contribution of Colombia. Government of Colombia Submission to the United Nations Framework Convention on Climate Change. Available at: https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party = COL

Government of Mexico. (2020). Nationally Determined Contributions. Government of Mexico Submission to the United Nations Framework Convention on Climate Change. Available at: https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party = MEX

Government of Nigeria. (2015). Nigeria's Intended Nationally Determined Contribution. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Nigeria%20First/Approved%20Nigeria%27s%20INDC_271115.pdf

Haines, A., Amann, M., Borgford-Parnell, N., Leonard, S., Kuylenstierna, J., & Shindell, D. (2017). Short-lived climate pollutant mitigation and the sustainable development goals. *Nature Climate Change*, *7*, 863–869. https://doi.org/10.1038/s41558-017-0012-x

IEA. (2016). World Energy Outlook – Special Report Energy and Air Pollution. International Energy Agency Special Report. Available at: https://webstore.iea.org/weo-2016-special-report-energy-and-air-pollution

IPCC. (2018). Global warming of 1.5°C An IPCC Special Report, Report of the Intergovernmental Panel on Climate Change.

IPCC. (2021). Assessment Report 6 Climate Change 2021: The Physical Science Basis.

Japan. (2021). Japan's Nationally Determined Contribution (NDC). Japan submission to the United Nations Framework Convention on Climate Change. Available at: https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party = JPN

Jonson, J. E., Borken-Kleefeld, J., Simpson, D., Nyíri, A., Posch, M., & Heyes, C. (2017). Impact of excess NOx emissions from diesel cars on air quality, public health and eutrophication in Europe. *Environmental Research Letters*, *12*(9). Article No. 094017. https://doi.org/10.1088/1748-9326/aa8850

Linnér, B. O., Mickwitz, P., & Román, M. (2012). Reducing greenhouse gas emissions through development policies: A framework for analysing policy interventions. *Climate and Development*, *4*(3), 175–186. https://doi.org/10.1080/17565529.2012.698587

Malley, C. S., Henze, D. K., Kuylenstierna, J. C. I., Vallack, H. W., Davila, Y., Anenberg, S. C., Turner, M. C., & Ashmore, M. R. (2017). Updated global estimates of respiratory mortality in adults ≥ 30 years of age attributable to long-term ozone exposure. *Environmental Health Perspectives*, *125*(8). Article No. 087021. https://doi.org/10.1289/EHP1390

Malley, C. S., Omotosho, D., Bappa, B., Jibril, A., Tarfa, P., Roman, M., Hicks, W. K., Kuylenstierna, J. C. I., de la Sota Sandez, C., & Lefèvre, E. N. (2021). Integration of climate change mitigation and sustainable development planning: Lessons from a national planning process in Nigeria. *Environmental Science & Policy*, *125*, 66–75. https://doi.org/10.1016/j.envsci.2021.08.022

Murray, C. J. L., Aravkin, A. Y., Zheng, P., Abbafati, C., Abbas, K. M., Abbasi-Kangevari, M., Abd-Allah, F., Abdelalim, A., Abdollahi, M., Abdollahpour, I., Abegaz, K. H., Abolhassani, H., Aboyans, V., Abreu, L. G., Abrigo, M. R. M., Abualhasan, A., Abu-Raddad, L. J., Abushouk, A. I., Adabi, M., … Lim, S. S. (2020). Global burden of 87 risk factors in 204 countries and territories, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. *The Lancet*, *365*(10258), 1223–1249. https://doi.org/10.1016/S0140-6736(20)30752-2

New Zealand. (2021). New Zealand's first Nationally Determined Contribution Updated 4 November 2021. New Zealand submission to the United Nations Framework Convention on Climate Change. Available at: https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party = NZL

Nigeria Federal Ministry of Environment. (2019). *Nigeria's National Action Plan (NAP) to reduce short-lived climate pollutants (SLCPs)*. Federal Ministry of Environment.

Oriental Republic of Uruguay. (2017). First Nationally Determined Contribution to the Paris Agreement. Oriental Republic of Uruguay submission to the United Nations Framework Convention on Climate Change. Available at: https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party = URY

Pauw, W., Cassanmagnano, D., Mbeva, K., Hein, J., Guarin, A., Brandi, C., Dzebo, A., Canales, N., Adams, K. M., Atteridge, A., Bock, T., Helms, J., Zalewski, A., F, E., Lindener, A., & Muhammad, D. (2016). *NDC explorer. German Development Institute / Deutsches Institut Für entwicklungspolitik (DIE), African Centre for Technology Studies (ACTS)*. Stockholm Environment Institute (SEI). https://doi.org/10.23661/ndc_explorer_2017_2.0.

Pauw, W. P., Klein, R. J. T., Mbeva, K., Dzebo, A., Cassanmagnago, D., & Rudloff, A. (2018). Beyond headline mitigation numbers: We need more transparent and comparable NDCs to achieve the Paris agreement on climate change. *Climatic Change*, *147*, 23–29. https://doi.org/10.1007/s10584-017-2122-x

Republic of Ghana. (2021). Updated Nationally Determined Contribution under the Paris Agreement (2020–2030). Republic of Ghana submission to the United Nations Framework Convention on Climate Change. Available at: https://www4.unfccc.int/sites/ndcstaging/Pages/Party.aspx?party = GH

Republic of Seychelles. (2021). Seychelles' Updated Nationally Determined Contribution. Republic of Seychelles submission to the United Nations Framework Convention on Climate Change. Available at: https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party = SYC

Romanello, M., McGushin, A., Di Napoli, C., Drummond, P., Hughes, N., Jamart, L., Kennard, H., Lampard, P., Solano Rodriguez, B., Arnell, N., Ayeb-Karlsson, S., Belesova, K., Cai, W., Campbell-Lendrum, D., Capstick, S., Chambers, J., Chu, L., Ciampi, L., Dalin, C., Dasandi, N., … Hamilton, I. (2021). The 2021 report of the lancet countdown on health and climate change: Code red for a healthy future. *The Lancet*, *398*(10311), 1619–1662. https://doi.org/10.1016/S0140-6736(21)01787-6

SEI, IISD, ODI, E3G, UNEP. (2021). The Production Gap Report 2021. Available at: http://productiongap.org/2021report

Shindell, D., Kuylenstierna, J. C. I., Vignati, E., van Dingenen, R., Amann, M., Klimont, Z., Anenberg, S. C., Muller, N., Janssens-Maenhout, G., Raes, F., Schwartz, J., Faluvegi, G., Pozzoli, L., Kupiainen, K., Hoglund-Isaksson, L., Emberson, L., Streets, D., Ramanathan, V., Hicks, K., … Fowler, D. (2012). Simultaneously mitigating near-term climate change and improving human health and food security. *Science*, *335*(80), 183–189. https://doi.org/10.1126/science.1210026

Stoner, O., Lewis, J., Martínez, I. L., Gumy, S., Economou, T., & Adair-Rohani, H. (2021). Household cooking fuel estimates at global and country level for 1990 to 2030. *Nature Communications*, *12*(1). Article No. 5793. https://doi.org/10.1038/s41467-021-26036-x

Togo Ministry of Environment. (2020). National Plan to Reduce Air Pollutants and Short-Lived Climate Pollutants in Togo. Togo Ministry of Environment Report. Available at: https://www.ccacoalition.org/en/resources/plan-national-de-r%C3%A9duction-des-polluants-atmosph%C3%A9riques-et-climatique

Togolese Republic. (2021). Revised Nationally Determined Contribution. Togolese Republic submission to United Nations Framework Convention on Climate Change (UNFCCC). Available at: https://www4.unfccc.int/sites/ndcstaging/Pages/Party.aspx?party = TGO&prototype = 1

UNEP. (2018). Integrated Assessment of Short-lived Climate Pollutants in Latin America and the Caribbean. United Nations Environment Programme/Climate and Clean Air Coalition report. Available at: http://ccacoalition.org/en/resources/integrated-assessment-short-lived-c

UNEP. (2019). *Air pollution in Asia and the pacific: Science-based solutions*. United Nations Environment Programme (UNEP). https://doi.org/10.13140/2.1.4203.8569

UNEP. (2021). Actions on Air Quality: A Global Summary of Policies and Programmes to Reduce Air Pollution. United Nations Environment Programme. Nairobi. Available at: https://www.unep.org/resources/report/actions-air-quality-global-summary-policies-and-programmes-redu

UNEP CCAC. (2021). United Nations Environment Programme and Climate and Clean Air Coalition. Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions. Nairobi: United Nations Environment Programme. ISBN: 978-92-807-3854-4. Available at: https://www.ccac

UNEP/WMO. (2011). Integrated Assessment of Black Carbon and Tropospheric Ozone. United Nations Environment Programme, World Meteorological Organisation Report. Available at: https://wedocs.unep.org/rest/bitstreams/12809/retrieve

UNFCCC. (2021). Nationally determined contributions under the Paris Agreement: Synthesis report by the secretariat. Conf. Parties Serv. as Meet. Parties to Paris Agreem. 02674, 32.

UNFCCC Secretariat. (2021). Nationally determined contributions under the Paris Agreement: Revised synthesis report by the secretariat. Available at: https://unfccc.int/documents/307628

United Nations. (2015). Paris Agreement, Available at: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

United Nations. (2016). Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer: Decision XXVIII/1: Further Amendment of the Montreal Protocol. Available at: https://ozone.unep.org/sites/default/files/2019-04/Original_depositary_notification_english_

United Nations. (2021). Glasgow Climate Pact. Decision -/CP.26. Available at: https://unfccc.int/sites/default/files/resource/cop26_auv_2f_cover_decision.pdf

United States of America. (2021). The United States of America Nationally Determined Contribution: Reducing Greenhouse Gases in the United State: A 2030 Emissions Target. United States of America Submission to the United Nations Framework Convention on Climate Change.

Vandyck, T., Keramidas, K., Kitous, A., Spadaro, J. V., Van Dingenen, R., Holland, M., & Saveyn, B. (2018). Air quality co-benefits for human health and agriculture counterbalance costs to meet Paris Agreement pledges. *Nature Communications*, *9*(1). Article No. 4939. https://doi.org/10.1038/s41467-018-06885-9

White House Office of Domestic Climate Policy. 2021. U.S. Methane Emissions Reduction Action Plan: Critical and Commonsense Steps to Cut Pollution and Consumer Costs, While Boosting Good-Paying Jobs and American Competitiveness. The White House Office of Domestic Climate Policy Document. November 2021.

WHO. (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. https://apps.who.int/iris/handle/10665/345329. License: CC BY-NC-SA 3.0 IGO.