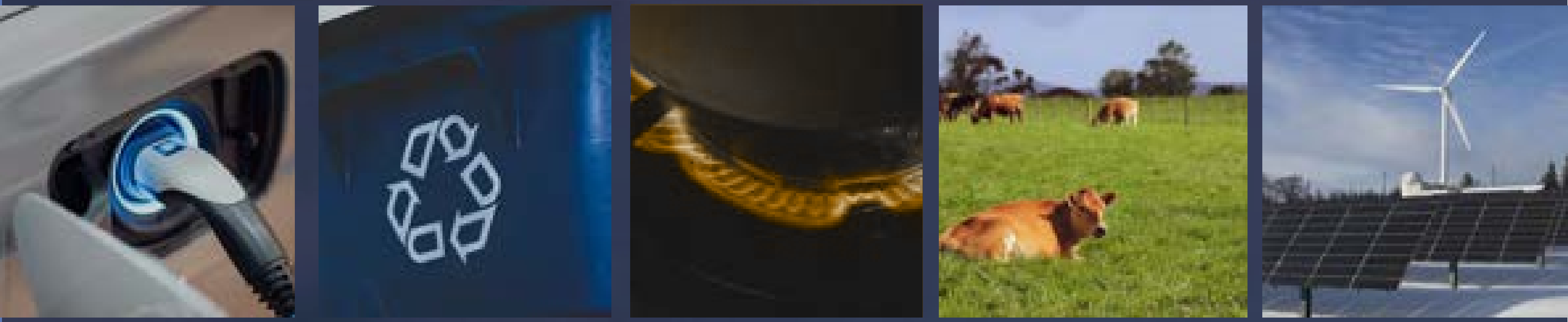
CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

ICAT
Initiative for Climate Action Transparency

Integrating Air Pollution and Short-Lived Climate Pollutants into Climate Change Transparency Frameworks:

A Practical Guide



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Design and layout: Dharmi Bradley; Copyediting: Nicholas Bradley

January 2023

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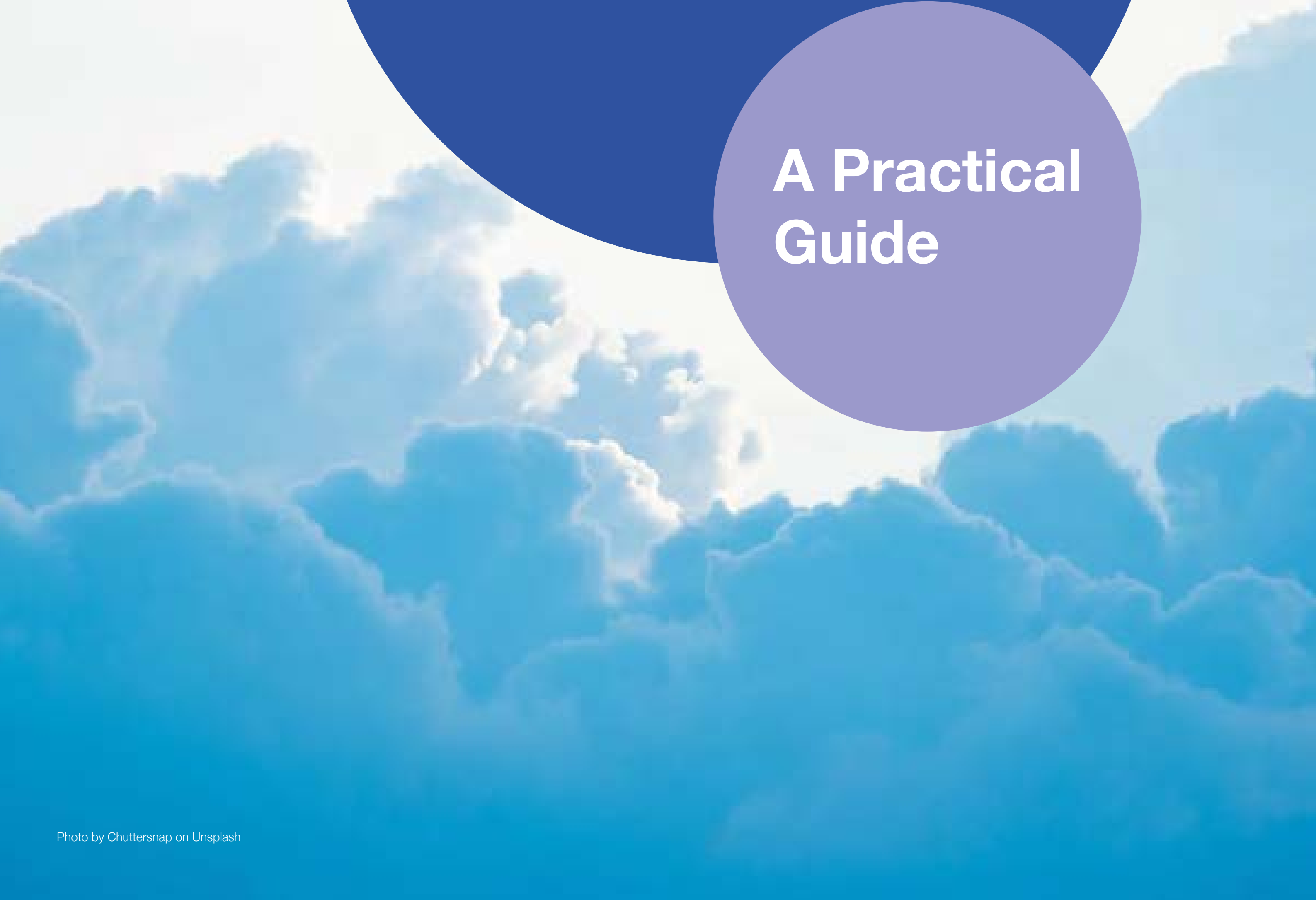

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Acknowledgements

The Climate and Clean Air Coalition is the only global partnership that addresses air pollution and climate change in an integrated way, through fast action to reduce short-lived climate pollutants – methane, HFCs, black carbon, and tropospheric ozone – that delivers multiple benefits for climate, health and development goals.

The Coalition was launched in 2012 as an action-oriented, flexible and multi stakeholder partnership. We have a strong track record of driving political and policy changes, of delivering sectoral mitigation actions, and advancing SLCP mitigation planning at the national and subnational levels, as well as increasing the scientific understanding of the importance of short-lived climate pollutant mitigation.

The Initiative for Climate Action Transparency (ICAT) provides countries with tailored support and practical tools and methodologies to build robust transparency frameworks needed for effective climate action, in sync with national development priorities. The Initiative works with over 40 developing countries ranging from large countries, like China, to small islands, such as Antigua & Barbuda. Established in 2015 at the COP that adopted the Paris Agreement, to support implementation of the Agreement's Enhanced Transparency Framework, ICAT's work is made possible by its donors: Austria; Germany; Italy; the Children's Investment Fund Foundation (CIFF); and ClimateWorks Foundation (CWF). The Initiative is managed by the United Nations Office for Project Services (UNOPS).

This report 'Integrating Air Pollution and Short-Lived Climate Pollutants into Climate Change Transparency Frameworks: A Practical Guide' was prepared as part of a joint Climate and Clean Air Coalition (CCAC) and Initiative for Climate Action Transparency (ICAT) funded project. It was developed by Aether, the Stockholm Environment Institute, George Washington University, the Council of Scientific and Industrial Research of South Africa (CSIR), and Clean Air Asia. The views expressed in this report are those of the authors and do not necessarily reflect the official positions of the CCAC and ICAT.

The authors are grateful for technical support, review, guidance and advice from colleagues at ICAT (Stefania D'Annibali, Oleg Bulyani, Henning Wuester, and Hannah Swee) and CCAC Secretariat (Nathan Borgford-Parnell, Seraphine Haeussling). The authors are particularly grateful to Elsa Lefèvre, formally of the CCAC Secretariat, who initiated the collaboration between CCAC and ICAT which produced this guide.

The authors are also grateful to the reviewers of the guide, including Machtelt Oudenes, Anil Markandya, Jongikhaya Witi, Miriam Hinostroza Suarez, Eduardo Calvo, Marlan Pillay

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Abbreviations and acronyms

NH_3	Ammonia
BC	Black Carbon
CH_4	Methane
CO_2	Carbon Dioxide
CO	Carbon Monoxide
$PM_{2.5}$	Fine Particulate Matter
PM_{10}	Fine plus coarse particulate matter
HCB	Hexachlorobenzene
HFC	Hydrofluorocarbon
NO_x	Nitrogen Oxides
N_2O	Nitrous Oxide
SO_2	Sulphur Dioxide
O_3	Tropospheric ozone

AFOLU	Agriculture, Forestry and Other Land Use
BR	Biennial Report
BTR	Biennial Transparency Report
BUR	Biennial Update Report
CCAC	Climate and Clean Air Coalition
CLRTAP	Convention on Long-Range Transboundary Air Pollution
EEA	European Economic Area
EMEP	European Monitoring and Evaluation Programme
ETF	Enhanced Transparency Framework
FOLU	Forestry and Other Land Use
GHG	Greenhouse Gas
GWP	Global Warming Potential
ICAT	Initiative for Climate Action Transparency
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
LEAP	Low Emissions Analysis Platform
MRV	Measurement, Reporting and Verification
NDC	Nationally Determined Contribution
NMVOC	Non-Methane Volatile Organic Compounds
NFR	Nomenclature for Reporting
SAAELIP	South African Emissions Licensing and Inventory Portal
SDG	Sustainable Development Goals
SLCF	Short Lived Climate Forcer
SLCP	Short-Lived Climate Pollutant
SNAP	Supporting National Action and Planning
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization
WWTP	Waste Water Treatment Plant

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1

Introduction

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Introduction

1

Continued climate change and poor air quality are among the world's largest and most pressing environmental risks. It is accepted that continued climate change, caused by the emission of greenhouse gases (GHGs) will cause major environmental destruction and increase the likelihood of extreme events such as floods, droughts, famine, and storms. In fact, the IPCC's Sixth Assessment Report (AR6) states with high confidence that climate change is already having an impact on human health, which will worsen, to over nine million climate-related deaths per year by the end of the century. At the same time, poor air quality is already responsible for millions of premature deaths every year, and will continue to have major impacts on wider human and environmental health.

Emissions of air pollutants that contribute to poor air quality are largely emitted from the same sources as GHGs. Implementing policies, actions, and mitigation measures that target and reduce emissions from major sources of both air pollutants and GHGs, therefore, offers a substantial opportunity to mitigate the impacts on the environment and human health.

A subset of both air pollutants and GHGs are Short-Lived Climate Pollutants (SLCPs). SLCPs are powerful climate forcers that remain in the atmosphere for a short time when compared to carbon dioxide (CO_2) but which have greater potential to warm the atmosphere in the short term. The main SLCPs contributing to global warming are black carbon, methane, tropospheric ozone, and hydrofluorocarbons.

Developing strategies and actions that reduce SLCP emissions have several key advantages.

Firstly, quick and coordinated reductions in emissions of SLCPs would reduce global warming in the short term and can play an important role in limiting global temperature increase to 1.5°C. Secondly, as the sources of SLCPs are major sources of GHGs and air pollution, actions that reduce emissions of SLCPs will also improve local and regional air quality, and reduce emissions of longer-term climate warmers, principally CO_2.

Therefore, there are clear benefits of integrating SLCPs and air pollutants into transparency frameworks developed in response to commitments on climate change through the Paris Agreement. Doing so acknowledges the impact of existing climate change plans on air quality, prioritises actions that have a meaningful impact on short-term warming, identifies additional mitigation actions that offer major environmental, public health, and socioeconomic benefits, and strengthen air quality management, in particular in countries where this is a nascent topic.

This guide aims to provide planners and decision makers with a practical document to outline specific steps in which the integration of air pollutants and GHG emissions, and therefore SLCPs, into a single transparency framework can be achieved. It is also structured to differentiate between the major steps, namely:

- **Development of an integrated emissions inventory including GHGs and air pollutants using a consistent methodology, including sector-specific considerations and ensuring consistency and comparability of methods and data.**
- **Evaluation of the impact on emissions of policies and measures to mitigate GHGs and air pollutants including an overview of policies and measures that offer multiple benefits and those that have trade-offs.**
- **Quantification of air pollution health burdens and benefits, including methods, data, and tools that can be used to estimate the health impacts.**
- **Integration into transparency frameworks, including steps to establish governance and institutional structures.**

2

Aims and Goals of this Guide

Photo by Dharmi Bradley

Key messages

1 There is a significant opportunity to take action on simultaneously improving air quality and mitigating climate change due to the large overlap in emission sources. This is particularly true for a subset of pollutants, SLPCs, as they simultaneously contribute to both issues.

2 Many countries have reflected this integration within their Nationally Determined Contributions (NDCs), either explicitly, or implicitly through the policies and measures identified to achieve their climate change targets.

3 There are many advantages to integrating tracking progress on air pollutants, SLCPs and GHGs. Such as promoting the implementation of coherent policies and measures, and increasing efficiency due to substantial overlaps in data requirements, and technical capabilities.

4 The aim of this guide is to show how methods and approaches used for tracking progress and evaluating policies and measures on climate change and air pollution can be effectively integrated.

5 This guide builds on existing guides on the integration of air pollutants and SLCPs within NDCs produced by the Climate and Clean Air Coalition (CCAC), and is aligned with the content of the previous Initiative for Climate Action Transparency (ICAT) policy assessment guide on Sustainable Development.

The links between climate change and air quality

Continued climate change and poor air quality are among the world's largest and most pressing environmental risks.

The consequences of climate change are well documented and include increased frequency of extreme weather events (such as storms, floods, droughts and heat waves), impacts on agriculture and food security, impacts on human health and biodiversity loss. Since pre-industrial times, global average temperatures have risen by 1.1°C (IPCC, 2021). To prevent major environmental destruction, the Paris Agreement sets the goal of limiting the increase in global average temperatures to "well below 2°C", and ideally to 1.5°C (United Nations, 2015). Current climate commitments, however, are not ambitious enough: estimates of warming despite the full implementation of climate change commitments submitted in 2015 were still greater than 3°C by 2100 (Rogelj et al., 2016), and updated pledges submitted in NDCs before the COP26 in Glasgow are consistent with 2.4°C (Climate Action Tracker, 2021), or 'just under 2°C' of warming (Meinshausen et al., 2022).

At the same time, an estimated 6.6 million premature deaths in 2019 has been associated to exposure to air pollution from indoor and outdoor sources, principally through respiratory and cardiovascular diseases (Murray et al., 2020). It is also linked to other non-fatal health effects, such as difficulties during pregnancy, asthma and emergency room visits (Anenberg et al., 2018; Malley et al., 2017).

The two air pollutants with the greatest impact on human health are fine particulate matter ($PM_{2.5}$) and ground-level ozone (O_3). Fine particulate matter is made up of different components. Some, such as black carbon and organic carbon, are known as primary $PM_{2.5}$, and are directly emitted into the atmosphere from different emission sources. However, a substantial fraction of $PM_{2.5}$ is secondary $PM_{2.5}$, which is formed through chemical reactions in the atmosphere from the emission of gaseous pollutants. This includes secondary inorganic $PM_{2.5}$, which is formed from emissions of nitrogen oxides (NO_x), sulphur dioxide (SO_2) and ammonia (NH_3), and secondary organic aerosol, which is formed

The issues of climate change and air pollution are closely linked because:

i. In many cases, GHGs and air pollutants are emitted from the same sources, such as residential cooking, industry, electricity generation, transport, agriculture and waste.

ii. Some of the substances contribute to both climate change and poor air quality, such as methane, black carbon and ground-level ozone, i.e. short-lived climate pollutants (SLCPs) (Figure 1) (IEA, 2016).

iii. Several Impacts overlap as they may effect the same ecosystems and aggravate the same health impacts.

from emissions of volatile organic compounds (VOCs; Fuzzi et al., 2015; Heal et al., 2012). Ozone, by contrast, is not directly emitted from anthropogenic sources, but is formed in the atmosphere through the photochemical reactions of NO_x, VOCs, methane (CH_4) and carbon monoxide (CO; Jenkin and Clemitshaw, 2000).

These links offer considerable opportunities to design strategies and identify measures that can simultaneously reduce air pollution and mitigate climate change. Global and regional studies have shown a range of strategies and actions that can be taken to target major sources of SLCPs and simultaneously improve local and regional air quality while reducing countries' contribution to global climate change. Common actions that offer co-benefits to climate change and air pollution include switching to renewable energy for electricity generation, improving energy efficiency, and improving waste collection and separation (CCAC SNAP, 2019; UNEP/WMO, 2011; UNEP, 2019). Some measures may also have trade-offs. For example, diesel vehicles incentivised in Europe in the 2000s for their lower CO_2 emissions compared to gasoline vehicles led to substantially higher black carbon particulate matter emissions, and poorer local air quality conditions.

A subset of both air pollutants and GHGs are SLCPs. SLCPs are powerful climate forcers that remain in the atmosphere for a short time period when compared to CO_2 but which have greater potential to warm (or to cool) the atmosphere in the short term. The main SLCPs that contribute to global warming are black carbon, methane, tropospheric ozone, and hydrofluorocarbons. Developing strategies and actions that reduce emissions of SLCPs several key advantages. Firstly, quick and coordinated reductions in emissions of SLCPs would reduce global warming in the short term and can play an important role in achieving the 2°C target set by the Paris Agreement. Secondly, as the sources of SLCPs are major sources of GHGs and air pollution, actions that reduce emissions of SLCPs will also improve local and regional air quality, and reduce emissions of longer-term climate warmers, principally CO_2.

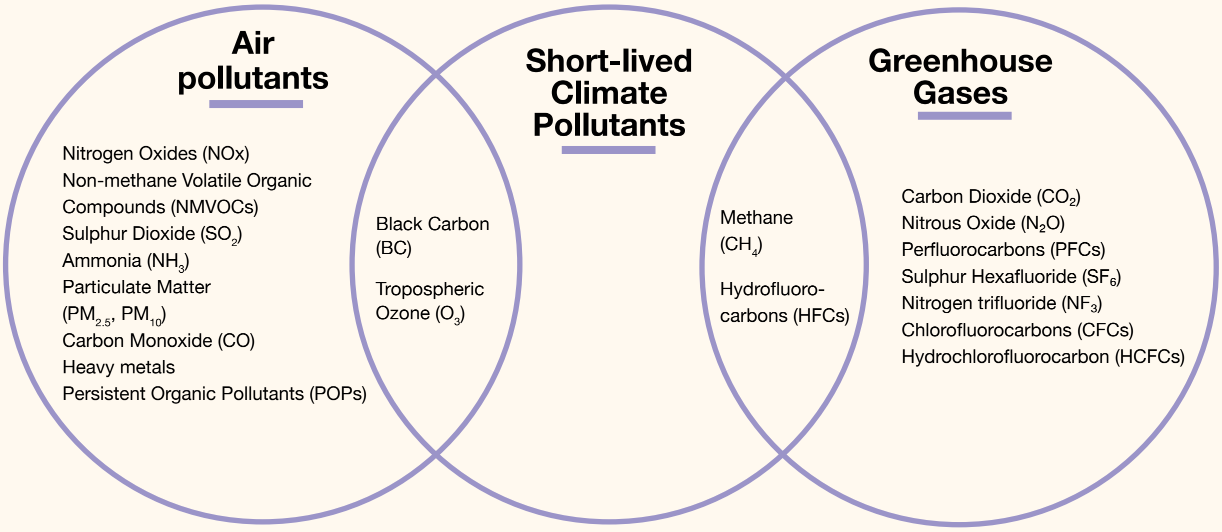

Figure 1: Summary of pollutants that are classified as air pollutants, short-lived climate pollutants and greenhouse gases

Photo by Daria Obymaha on Pexels

Reducing emissions of GHGs, air pollutants, and SLCPs offer substantial environmental, public health, and socioeconomic benefits. Therefore, developing an integrated framework that enables all three groups to be considered during policy design and tracked during action implementation offers policy makers a major opportunity to develop pathways that maximise benefits, whilst also identifying policies, whether existing or planned, that may have detrimental side effects requiring further mitigation.

A mandatory element of the Paris Agreement is the reporting of progress in climate change mitigation, adaptation, and support provided or received. Reporting under the Enhanced Transparency Framework (ETF) includes the submission of national GHG emission inventories and evaluations on the progress of policy and measure implementation outlined in NDCs.

In most cases, satisfying the requirements of the ETF is done separately from air quality management, where, whilst some countries have systems for tracking progress on reducing air pollutant emissions, most currently lack appropriate systems. Air pollution and climate change are often managed through different national planning and policy making processes. In some cases the management of air quality and climate change is the responsibility of different organisations and ministries, and can also be governed differently between national, regional, and local governments.

Instead of treating air quality issues in isolation, systems and processes put in place to allow countries to satisfy the requirements of reporting under the ETF can be further enhanced through the integration of air pollutant data. The resultant system would encompass SLCP emissions, allow for mitigation policy and measure development targeted at reducing their emissions. There are numerous other benefits of considering greenhouse gases and air pollutants in tandem, including:

Efficient data gathering, quality assurance, and analysis - there are significant opportunities to enhance the efficiency of delivery and knowledge transfer by integrating air pollution and GHG data gathering and analysis. Air pollution and climate change analysis have largely common sources of data (e.g., national statistics, industrial regulatory reporting, sectoral strategies, see **Section 3**), overlapping sectoral and data science expertise and common policy and decision-making ministries. Standardised data flows, metrics, indicators, and tools can be developed, and value can be added by combining insights for decision makers on positives and negatives of different strategies for GHGs and air pollution. Combined and enhanced decision support tools can also be developed, including those looking at cost-benefit analyses.

Use of consistent reporting and methodologies in inventory and action impact calculations – Integrated GHG and air pollutant inventories and projection analyses (discussed further in **Section 3** and **Section 4**) offer an opportunity to ensure consistent reporting and methodology, as well as ensuring that quality assurance activities on collected data can be focussed and consistent. The guidance documents use a standardised categorisation of sources which promotes consistency of the data source requirements for both types of emissions inventory, whilst outlining methodologies and approaches to quantify emissions. Channelling expertise and knowledge into a single effort would ensure the same decisions are being made in GHG and air pollutant calculations in terms of data handling, use of assumptions, and methodologies, thereby **enhancing the national environment evidence and knowledge base,** and increasing confidence in decision-makers that the evidence the system provides is clear and reliable. Clarifying the evidence base in this way would also minimise the potential for conflicting messages of priorities emerging from disparate governmental and non-governmental stakeholders.

Promotion of policies and measures that yield multiple environmental benefits for climate change mitigation and improving air quality, as key sources can be more readily identified and mitigation actions developed that simultaneously reduce emissions of multiple pollutants. Emissions are often projected into the future for different scenarios to support this policy development phase, as discussed in **Section 4**. For air pollution, changes in emissions can then be used as input into more detailed assessments, such as evaluating the likely change in air pollution concentrations, exposure, and associated health impacts in each of the future scenarios, as discussed in **Section 5**. Abatement strategies can therefore also achieve demonstrable global climate benefits as well as more locally based air quality benefits.

There are an increasing number of countries adopting an integrated approach to work on climate change mitigation and air quality improvement. For example, in Europe, most countries develop national GHG emission inventories for reporting to the United Nations Framework Convention on Climate Change (UNFCCC), and national air pollutant emission inventories for reporting under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) together, using common data collection, quality control and analysis platforms (Maas and Grennfelt, 2016). The centres of excellence that generate these outputs also support decision makers with more detailed data on air pollutant and GHG sources and sinks.

Countries outside the CLRTAP have also begun to integrate SLCP and air pollutant emissions into their national GHG emission inventory systems. For example, the national GHG inventories of Chile, Costa Rica, Ghana, and Mexico have all included air pollutant emissions within them, as reported in national submissions to the UNFCCC (Ghana Environmental Protection Agency, 2019; Government of Chile, 2020; INECC, 2019). Some countries have also submitted climate change commitments in their NDCs that emphasise the importance of reducing air pollution and the subsequent positive impact on public health alongside reducing GHGs (Malley et al., 2022). For example, Nigeria updated its NDC in 2021 to include mitigation of SLCPs and highlighted that the implementation of all mitigation measures included in the NDC would reduce black carbon, methane, $PM_{2.5}$ and nitrogen oxide emissions by 42%, 28%, 35%, and 65, respectively in 2030 compared to the baseline scenario (Federal Ministry of Environment Nigeria, 2021).

> "….implementation of Nigeria's NDC would result in substantial local benefits for human health through reduced air pollution exposure, in addition to its climate change mitigation benefits"
>
> Nigeria's NDC 2021

Furthermore, Nigeria’s NDC specifically quantifies the health benefits that could be achieved from reduced household air pollution exposure, by taking actions to switch to cleaner fuels (Liquified Petroleum Gas (LPG) for example). This health benefit was quantified using the approaches outlined below for each specific mitigation action included in Nigeria’s NDC related to household air pollution, to quantify the health benefits from specific mitigation actions included in Nigeria’s NDC:

> “By taking the steps… to encourage cleaner cooking, 30,000 premature deaths could be avoided by 2030, in addition to the significant carbon savings”
>
> Nigeria’s NDC 2021

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Harry Wedzinga

Several countries have set specific targets within NDCs that are designed to achieve simultaneous human health benefits. Colombia, Chile and Mexico have each included a supplementary target, in addition to an economy-wide GHG reduction target, to reduce BC emissions (Government of Chile, 2020; Government of Colombia, 2020; Government of Mexico, 2020). These targets were set through following an integrated assessment of air pollutant, SLCP and GHG emission mitigation assessment, in which specific policies and measures were evaluated to determine the extent to which they could reduce BC alongside GHGs. The recommendations from these quantitative assessments were used as input and evidence to the political process of setting climate change mitigation targets in the NDC. Colombia's NDC, submitted in 2021, states that the rationale for this target includes the contribution of BC to the deterioration of air quality and as a major environmental risk factor for human health, in addition to its impact on climate change. Finally, the updated NDC of the United Kingdom states that the UK's support decarbonisation approaches that strive to improve air quality and minimise adverse impacts on human health, are balanced with action to achieve reductions in carbon emissions.

For those countries that have already integrated air pollutants and SLCPs, such as those highlighted above, the impacts of the full implementation of their NDCs can now be monitored, reported, and verified for SLCPs and air pollutants in addition to GHGs. This can establish the effectiveness of policies and measures and the prioritisation of additional mitigation actions based on both the GHG emission reductions and air pollutant and SLCP benefits that could/have been achieved from their implementation. For those that have not yet built an integrated approach, there is an opportunity to adapt the systems that will be used to assess progress towards implementation of their NDCs in the development of the first round of Biennial Transparency Reports in 2024, to include air pollution and SLCPs. By doing so, the co-benefits of NDC implementation, such as those for air quality and public health, can be evaluated and reported, and a suite of systems, governance structures, and tools developed that enable for more effective and impactful policies to be developed in future.

This guidance uses case studies where appropriate to highlight the approach taken and lessons learned during the development of these integrated systems.

Aims of this guide

This practical guide is a joint effort by the CCAC and ICAT that aims to illustrate how GHGs and air pollution can be considered in an integrated way across the key elements of Measurement, Reporting and Verification (MRV) frameworks. Within this guide, MRV frameworks are defined as the systems and governance structures set up to facilitate UNFCCC requirements on international and domestic MRV, which aim to enable:

Measurement of GHG emissions, actions planned or undertaken to mitigate emissions, constraints and gaps, and support needed or received

Reporting of these elements in National Communications or Biennial Transparency Reports (BTR)/ Biennial Update Reports (BUR)

Verification through the international consultation and analysis process

In addition, there is also a forward-looking aspect to transparency under the Paris Agreement, in terms of reporting on projections and policy and measures designed to achieve a country's climate change commitments.

There is no formal, global MRV process for air pollution but there are processes of tracking progress in regional agreements (e.g. CLRTAP) and at national scales. While MRV focuses on the implementation of actions and the change in emissions and impacts that result, planning and strategy development undertakes an assessment of the benefits that could accrue from implementing different actions, the pathways, barriers, and strategies to overcome those barriers.

This guide is a joint effort by the CCAC and ICAT that aims to provide a practical approach for how countries can integrate the assessment and tracking of the climate change, air pollution and public health impacts of policies and actions into their MRV frameworks. This guide outlines how an integrated approach can be adopted for:

Emissions inventories, including sector-by-sector advice that can enable for the full integration of GHGs, air pollutants and SLCPs

Assessment of the impact of GHG, air pollutant, and SLCP mitigation policies and measures, including an overview of how the mitigation impacts can be quantified and compiled to build emissions scenarios

Quantification of the health benefits of action to mitigate GHGs and air pollutants

Other elements of MRV frameworks, including establishing the institutional arrangements that can facilitate this integration

Aims and Goals of this Guide

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How to use this guide

This guide is aimed at climate change and air quality planners and decision makers working at the national scale on emission reduction and policy development.

After reading this guide, climate change planners should have a clear understanding of why, and how SLCPs and air pollutants could be integrated into their MRV framework. This guide offers insights on how they can increase the acceptance for climate change mitigation by creating synergies with air quality management, and offer insights into how aligning and integrating air pollution with climate change planning could provide new tools to understand and track progress on the magnitude and contribution of different air pollutant emissions, and their impacts on human health.

The role of this guide is to provide readers with an overview of how assessments of climate policy can be undertaken to identify and quantify the impact on air pollution, SLCPs, and public health, and how the co-benefits of implemented policies can be monitored, reported, and verified. This can be used by countries that have already explicitly linked air pollution and climate change mitigation within their national planning processes to jointly track progress on the achievement of existing climate change and air pollution targets. Most countries have implicitly included actions in their climate change planning and commitments which will achieve air pollution benefits. This guide provides a practical method by which the air pollution benefits of climate change mitigation action can be tracked, and emphasised as a local development benefit of achieving international climate change commitments. Finally, for those countries which lack capacity and formal air pollution and/or climate change planning processes, the present guide provides the basis for establishing systems to increase national capacity on two important environmental issues simultaneously.

Readers should use this guide to understand the opportunities and efficiencies that can be leveraged when undertaking this integration. All Sections of this guide include reference to key international guidance, data sources and other materials that should be used to operationalise the integration outlined in this guide. Also included are case studies that illustrate how the approaches outlined have been previously applied, which highlight technical considerations, as well as institutional barriers and how they have been overcome.

Links to other guides

The guide builds on previous reports produced by CCAC and ICAT and can be used in combination with these other materials. It is part of a series developed by ICAT to help countries assess the impacts of climate change mitigation policies and actions in multiple areas, including GHG emission reduction potential, and on different Sustainable Development Goals (SDGs). The guide also supplements existing guidance produced by CCAC National Planning hub. These include the CCAC Supporting National Action and Planning (SNAP) guidance on national planning to reduce SLCPs, and on integrating air pollution and SLCPs into NDCs which are also summarised below. These cover broader integrated air pollution and climate change planning topics than are covered in this guide.

The report Opportunities for Increasing Ambition of NDCs through Integrated Air Pollution and Climate Change Planning: A Practical Guidance document outlines four ways in which SLCPs and air pollutants can be integrated into climate change commitments within NDCs and provides a methodology for the inclusion of SLCPs and air pollutants within GHG mitigation assessments that often underpin an NDC emission reduction target (CCAC SNAP, 2019). These four approaches emphasise the inclusion of specific mitigation measures within NDC documentation to underpin climate change mitigation targets, as the mitigation measures determine the extent to which SLCPs are reduced alongside GHGs and air pollutants.

In this guide, the information provided in **Sections 3, 4 and 5** build on the CCAC Supporting National Action & Planning to reduce SLCPs (SNAP) initiative and its guidance in several ways:

1. This guide provides methods by which air pollutants and SLCPs can be integrated into the MRV frameworks that track progress on the commitments made within NDCs. For those countries that have integrated SLCPs and air pollutants into their NDCs, this guide provides a practical way to move forward and track progress on the extent to which air pollutants and SLCPs are changing as the NDC begins implementation, as well as demonstrating the achievement of air pollution benefits from NDC implementation.

2. This guide provides sector-specific information on how SLCPs, air pollutants and GHGs can be integrated into MRV frameworks, GHG emission inventories and the assessment of policies and measures. This provides more specific detail than the CCAC SNAP report on how assessment of GHG, SLCP and air pollutant emissions can be estimated in an integrated analysis for each of the major emitting source sectors.

3. Finally, for those countries that have not yet included SLCPs or air pollutants within their NDCs, this guide provides a practical approach to building the evidence base to understand the link between air pollution and climate change in a particular country, the major sources where SLCP, air pollutant and GHG emissions overlap, and the potential mitigation options which could achieve multiple benefits for air quality, health, and climate change.

In the context of Sustainable Development Goals (SDGs), air pollution is explicitly included under:

3 GOOD HEALTH AND WELL-BEING

Good health and wellbeing - 3.9

“By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination”

11 SUSTAINABLE CITIES AND COMMUNITIES

Sustainable cities - 11.6

“By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management).”

This guide focuses on how air pollution can be integrated into climate-focused MRV frameworks. Although air pollution is just one of a large number of sustainable development goals linked to climate change mitigation actions, it has significant importance and offers opportunities of alignment. It is intended to be used in combination with other guides such as the ICAT Sustainable Development Methodology, which deals with the broader issue of how SDGs can be an integral part of climate change reporting and the evaluation of subsequent mitigation policies and action. The ICAT Sustainable Development methodology aims to inform how countries report on the progress made in implementing their NDCs, and the support needed within the Enhanced Transparency Framework.

Within the ICAT Sustainable Development guide, a methodology is outlined for how countries can evaluate the Sustainable Development impacts of specific climate policies (Figure 2). The methodology first defines the objective of the assessment, and whether it is intended to evaluate prospective policies being considered to mitigate climate change, or whether the assessment being undertaken is to evaluate the sustainable development impacts of an existing policy. The Sustainable Development indicators are then selected, and qualitative and/or quantitative methods used to assess the effect of the policy on a particular sustainable development goal (SDG), which can then be updated and monitored over time. The ICAT Sustainable Development guide is part of ICAT's wider range of policy assessment guides, which provide a step-by-step process for estimating the GHG impacts of specific climate actions and policies for a wide range of sectors. These steps can be readily extended to incorporate air pollution and SLCPs more explicitly (See **Section 5**). A number of other resources and tools are also available in ICAT's Climate Outcomes and Mitigation Policy Assessment (COMPASS) toolbox, intended to support decision-makers and analysts in their assessment of the impact of climate policies and actions.


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This guide focuses on air pollution and SLCPs, but the methodology outlined in the ICAT Sustainable Development guide can also be applied alongside this document. For example, air pollution, and its impacts on health are included within the SDG framework, as specific targets, i.e.:

1. **SDG target 3.9.1, reduction in deaths and illnesses from air pollution.**

2. **SDG target 11.6.2, reduce the environmental impact of cities by improving air quality**

Using the ICAT Sustainable Development methodology users can identify those climate change policies that are likely to impact air pollution, alongside other SDGs. Having identified those climate change policies impacting air pollution, this guide can then be applied to ensure that the implementation of those climate change policies enables the monitoring of their impact on air pollution, and associated health impacts, in addition to their impact on GHGs and/or SLCPs.

Advancing climate action through the enhanced transparency framework

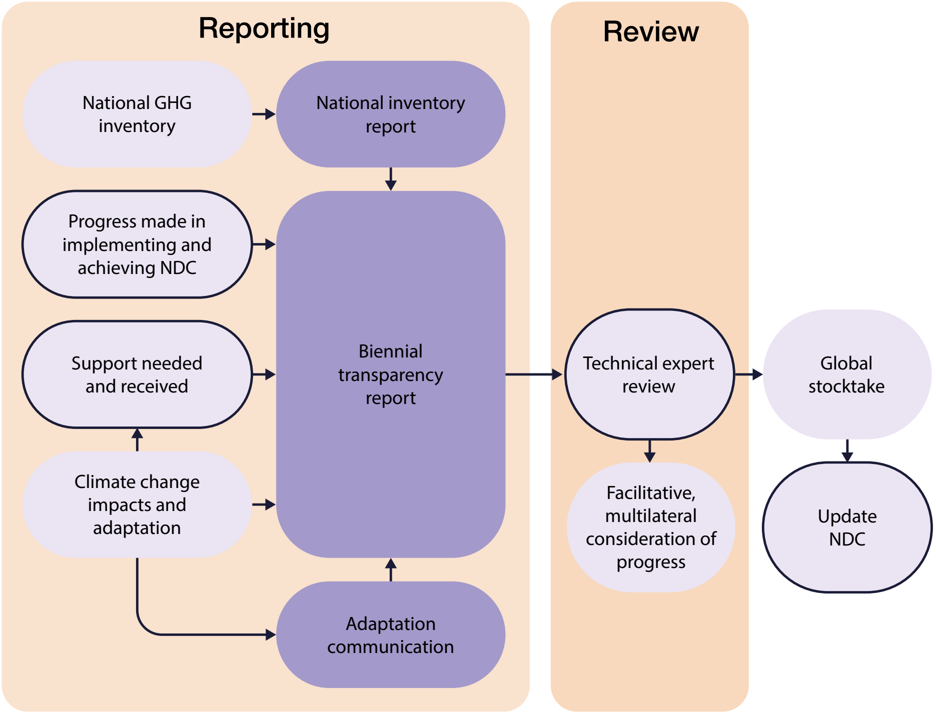

Figure 2: Overview of how ICAT Assessment Guides can be used to inform inputs to Enhanced Transparency Framework under the Paris Agreement (Source: ICAT Sustainable Development Methodology Executive Summary).

□ Reporting inputs and aspects of the transparency framework

■ Reports under the transparency framework

▢ ICAT assessment guides can help with reporting inputs and aspects of the transparency framework

By helping policymakers assess the impacts of policies and actions, the ICAT assessment guides can help countries track progress in implementation and further develop their NDCs towards enhanced ambition. The ICAT assessment guides can also help provide the necessary information for countries to report under the Paris Agreement's enhanced transparency framework.

Although assessment of sustainable development impacts is optional in the enhanced transparency framework, a decision of the 24th Conference of the Parties to the UNFCCC (COP24) mandates that all countries voluntarily participating in Article 6 cooperative approaches promote sustainable development. Increasingly, integrated assessments to track progress of NDC and SDG implementation are called upon to promote synergies and avoid trade-offs between multiple objectives.

Assessing the diverse sustainable development and climate impacts of polices and actions in an integrated manner is helpful for policy design, steering implementation towards desired goals, and leveraging enhanced ambition for NDC implementation to achieve global sustainable development and climate goals.

The following sections highlight the **quantitative** ways in which air pollutants and SLCPs can be integrated into the monitoring and assessment of climate change policies. **Section 3** and **Section 4** highlight how emissions of air pollutants and SLCPs can be integrated into GHG emission inventories and policy assessments, respectively. **Section 5** highlights how the impacts of air pollution on human health can be quantified and evaluated for climate change policies and measures, either ex-post or ex-ante. **Section 6** provides details of how to set up MRV frameworks that facilitate the integration of air pollution and GHG assessments, and features a step by step outline detailing how to set up MRV frameworks that enable the integration of SLCPs, air pollution and climate change. **Section 7** provides a range of country case studies.

3

Integrating Short-Lived Climate Pollutants and Air Pollutants into National GHG Inventories

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Key messages

1. **Developing integrated air pollutant, SLCP and GHG emission estimates is facilitated by the substantial overlap in methodologies and data requirements, and the international guidance documents for air pollutant and GHG emission inventories. This means that with an existing GHG emission inventory, a country can relatively quickly and easily also estimate national total air pollutant emissions.**

2. **Many of the key activity data required to estimate GHG, SLCP and air pollutant emissions is the same, meaning that common and existing processes for activity data collection can be used to develop inventories covering all pollutants.**

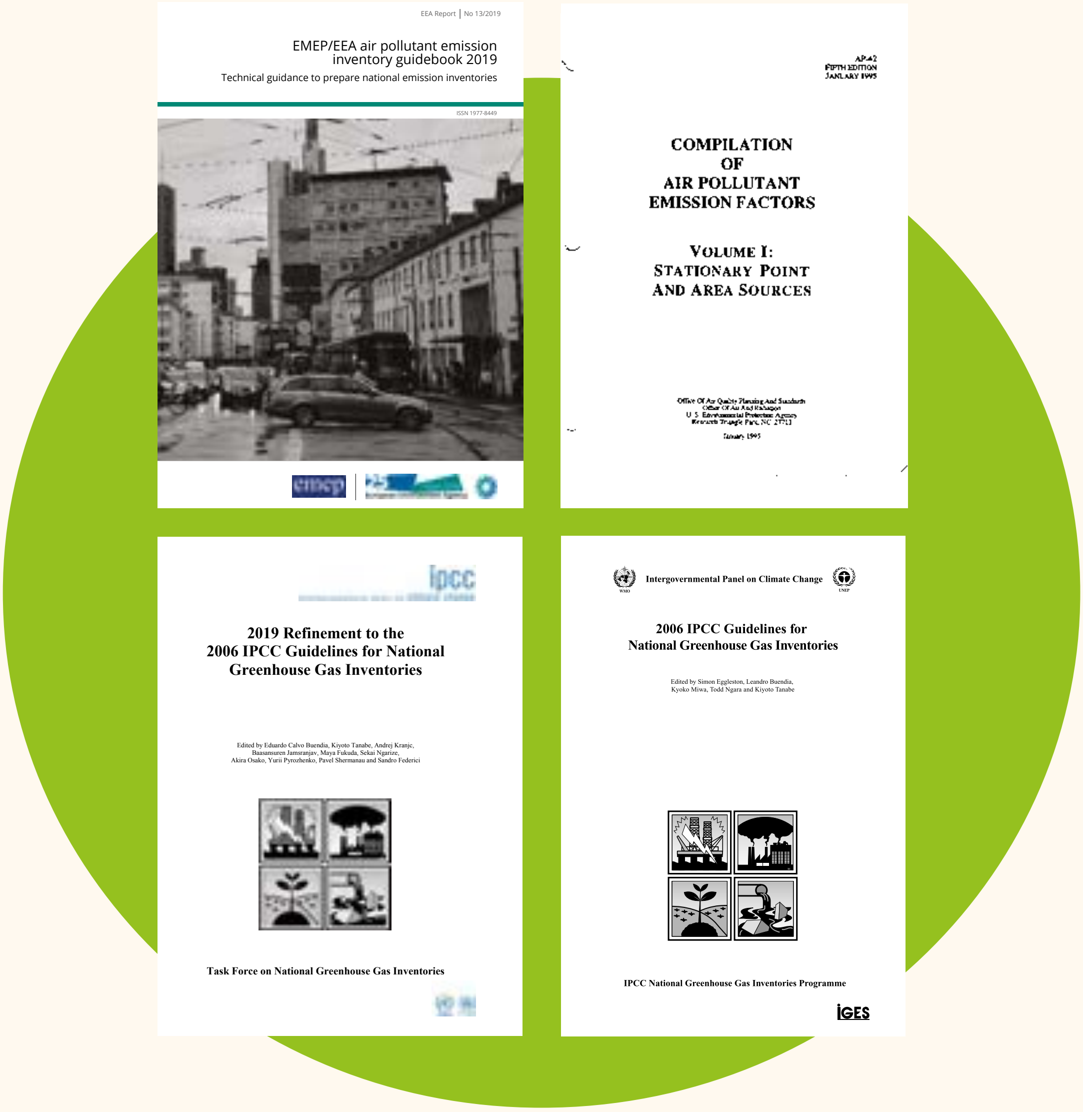
3. **For more detailed assessments, there are also some differences. While GHG emissions are typically reported at the national scale, to assess the impact of air pollutants on human health, greater spatial disaggregation is often required to understand where air pollutants are emitted, and their relationship with major population centres.**

4. **Sector-specific methods can also differ. For some sectors (e.g. energy), there can be air pollutant-specific control technologies that can reduce emissions and need to be accounted for in emission estimates, but do not reduce GHG emissions. For biomass consumption, air pollutants are emitted at the point of combustion, but carbon dioxide emissions are accounted for under the Forestry sector.**

5. **While emissions of different GHGs can be aggregated to a total GHG emission using Global Warming Potential, the same approach cannot be taken with air pollutants and SLCPs, due to the different ways that they impact air quality and climate. Emissions should be reported in mass units of each pollutant.**

The quantification of the emissions of GHGs into the atmosphere is a fundamental part of national climate change monitoring and reporting. Almost all countries in the world have official estimates of the magnitude of their GHG emissions. To support the development of comparable and transparent GHG emission inventories, the IPCC has developed national GHG emission inventory guidelines (IPCC, 2006, 2019). The IPCC Guidelines for National Greenhouse Gas Inventories (hereafter IPCC Guidelines) provides methodologies, as well as default data to develop a comprehensive accounting of GHGs from all national sources (and sinks). The IPCC Guidelines include methods to estimate emissions of CH_4 and HFCs.

For air pollution, there is not currently a global emission inventory guidebook. However, the European Monitoring and Evaluation Programme (EMEP) / European Environment Agency (EEA) Air Pollution Emission Inventory Guidebook (hereafter EMEP/EEA Guidebook) is a comprehensive set of methodologies that can be used to quantify emissions of air pollutants, but has been developed with a focus on providing guidance to European countries reporting air pollutant emission inventories under the Convention on Long-Range Transboundary Air Pollution (EMEP/EEA, 2019). The EMEP/EEA Guidebook includes methods to estimate emissions of black carbon.


EEA Report | No 13/2019

EMEP/EEA air pollutant emission
inventory guidebook 2019

Technical guidance to prepare national emission inventories

ISSN 1977-8449

AP-42
FIFTH EDITION
JANUARY 1995

COMPILATION
OF
AIR POLLUTANT
EMISSION FACTORS

VOLUME I:
STATIONARY POINT
AND AREA SOURCES

2019 Refinement to the
2006 IPCC Guidelines for National
Greenhouse Gas Inventories

Edited by Eduardo Calvo Buendia, Kiyoto Tanabe, Andrej Kranjc,
Baasansuren Jamsranjav, Maya Fukuda, Sekai Ngarize,
Akira Osako, Yurii Pyrozhenko, Pavel Shermanau and Sandro Federici

Task Force on National Greenhouse Gas Inventories

Intergovernmental Panel on Climate Change

2006 IPCC Guidelines for
National Greenhouse Gas Inventories

Edited by Simon Eggleston, Leandro Buendia,
Kyoko Miwa, Todd Ngara and Kiyoto Tanabe

IPCC National Greenhouse Gas Inventories Programme

Figure 3: International guidance on the development of emission inventories for air pollution and greenhouse gases.

The IPCC Guidelines includes methods for quantifying emissions of greenhouse gases. However, it does not provide methods for the quantification of emissions of pollutants which are precursors to GHGs. For example, tropospheric ozone is a GHG that is not directly emitted but is formed in the atmosphere from emissions of carbon monoxide, methane, nitrogen oxides and non-methane volatile organic compounds. These precursors are also air pollutants, and methodologies for their quantification are included in the EMEP/EEA Guidebook. The IPCC Guidelines recommends that the EMEP/EEA Guidebook is used for the quantification of these precursors, and other non-GHG climate forcers, and provides a mapping of the sources of these precursors that are covered in the EMEP/EEA guidebook. In 2019, the IPCC agreed to expand its methodologies to include all 'short-lived climate forcers (SLCFs)'. This means that subsequent refinements to the IPCC Guidelines will provide globally-applicable methods for quantifying emissions of all air pollutants contributing to particulate matter formation, in addition to tropospheric ozone.

In general, emissions inventory methods can be simplified to:

$$\text{Emissions} = \text{Activity} \times \text{Emission Factor} \qquad (1)$$

In addition to the harmonised international guidance documents for quantification of GHGs and air pollutant emissions, there is also a common classification system for their sources. The Nomenclature for Reporting (NFR) source classification system is the basis for the disaggregation of both GHG emission sources within the IPCC Guidelines, and for air pollutants within the EMEP/EEA Guidebook. This has facilitated the development of consistent methodologies for GHG and air pollutant emission inventory development, and consistent reporting. The large overlap in approaches to the quantification of GHG, SLCPs and air pollutant emissions stems from a large amount of common input data and data providers. Equation 1 simplifies the general approach to estimating emissions and/or removals.

Emissions calculations are based on the multiplication of: i) an activity variable (e.g. fuel consumption of a type of fossil fuel, numbers of a type of livestock, hectares of a type of mature forest), by ii) an emission (or removal) factor, which captures the mass of a pollutant per unit of activity. This equation provides a common basis for the quantification of GHGs and air pollutants for most emission source sectors.

As a result of the common source sector classification and international emission inventory guidance, there is a common set of **activity data** that can be used for the quantification of GHG and air pollutant emissions. For example, in the energy sector, the most basic approaches to quantification of GHG and air pollutant emissions use fuel consumption to quantify emissions. In both sets of guidance, a suite of default emission factors are available that are directly applicable in the most basic approaches, aligning with the type of activity variable suggested for a given source. **Section 7** provides some case studies highlighting how the commonality in activity data has led to the development of integrated emission inventories in Colombia, Ghana and Norway.

Each guidance offers methodologies of differing complexities for each source. Tier 1 methods are the simplest approach to quantifying emissions from a particular emission source. They often require aggregated, readily available national statistics for the activity variable, and have default emission factors available. Tier 2 methodologies are more complex and include a greater level of detail/disaggregation of activity variables. For the majority of Tier 2 approaches, default emissions factors, defined at this more detailed level are available. Finally, Tier 3 are the most detailed methods for quantifying emissions, and often require data on individual facilities (e.g., in the case of energy industries) or rely on detailed national statistics. Tier 1 methodologies are recommended only to be applied when data to use higher Tier methods are not possible given data availability and are not recommended for key sources.

As a result of the overlap between methods for quantifying air pollutant and GHG emissions, many countries have harmonised the development of national GHG, SLCP and air pollutant emission inventories, and have reported an expanded set of pollutants within their climate change reporting.

Developing a black carbon inventory in Colombia

Colombia's first black carbon emission inventory was developed in 2016 and was endorsed and published by the institution also responsible for the national GHG emission inventory in 2016 (Institute for Hydrology, Meteorology, and Environmental Studies (IDEAM)). The development of the BC emission inventory also included other air pollutants, and while not developed with the national GHG emission inventory, used a consistent set of data and statistics. As a result of developing the BC emission inventory, Colombia was able to establish a target for the reduction of black carbon within its updated NDC submitted in 2020.

For greenhouse gases, the regular development of national emission inventories provides a reference against which emission reductions can be framed and stated in documents like NDCs. The development, and endorsement of a national black carbon emission inventory by IDEAM provided the corresponding reference point against which a BC target could be set (IDEAM, 2020). This is shown in the 2020 NDC, in which the black carbon reduction target is a reduction of 40% compared to 2014 levels (Government of Colombia, 2020). The 2014 black carbon emissions were those published by IDEAM in the national black carbon emission inventory. A national institution such as IDEAM developing this inventory meant that as well as providing the emission levels for setting the target, there is a national institution capable, and responsible for updating the national emission inventory for black carbon at regular intervals to monitor black carbon emissions against the target as the NDC is implemented.

There can be multiple other advantages of an integrated air pollutant and GHG inventory, including:

1. **Greater appreciation of important sources of GHGs, SLCPs, and air pollutants:** An understanding of the national total SLCP and air pollutant emissions, and the contribution from each source can provide a first order understanding of the key sources and their broad order of magnitude contribution nationally to air pollutant emissions. Regularly updating national total SLCP and air pollutant emissions allow trends in emissions to be assessed, to understand how drivers of activity in key sectors may be increasing emissions, or how implementation of policies and measures may be reducing emissions.

2. **More informative and interlinked air pollution impact assessments:** Quantifying national total air pollutant emissions does not provide a comprehensive assessment of air quality within a country, because *where* air pollutants are emitted and their dispersion plays a much larger role in determining the impact of air pollutant emissions on human health, ecosystems, and crop production. Therefore, to understand the impacts of air pollution, the location of the air pollutant emissions needs to be known, as well as the magnitude of the emission. By contrast, emissions of GHGs and their impact on climate change are less dependent on the location in a country where they are emitted compared to the total magnitude of emission. For SLCFs like black carbon, their climate impact is determined by the location where they are emitted. There is international guidance on how national (or other geographic area) total emissions can be spatially distributed to fine spatial resolution (EMEP/EEA Guidebook, 2019, Part A Chapter 7). This guidance generally includes methods by which proxy variables, such as population, road network density, livestock and crop land distributions, can be used to spatially distribute emissions.

3. **Efficiencies that can be gained in terms of avoiding duplication of data collection, processing, and management processes and systems:** as data sources required for emissions estimates are often common between the IPCC Guidelines and EMEP/EEA Guidebook, integration of the inventory process can streamline efforts to collect, clean, and process data.

4. **Application of consistent methodologies and QA/QC procedures:** It also ensures consistency in the approaches used to handle data, the methodologies used where appropriate, and the harmonisation of the QA/QC procedures to ensure the transparency, consistency, comparability, and accuracy of the results. It also ensures that sectoral experts can have greater oversight of emissions calculations and processes.

Photo by Markus Distelrath on Pexels

However, despite the substantial overlap in methodologies and activity data needed to quantify GHG and air pollutant emissions, there are also significant differences that need to be taken into account to: i) ensure the robustness and accuracy of SLCP and air pollutant emission calculations, ii) to allow impacts of SLCP and air pollutant emissions to be quantified, and iii) to facilitate the assessment of policies and measures and their impact on GHGs, SLCPs and air pollutants. These challenges include:

Balancing competing interests for all categories of importance: Sometimes there are competing GHG and air pollutant priorities and therefore more key categories to manage. For example, in many countries electricity generation is a key category for GHG emissions, but may make a smaller contribution to air pollutant emissions if thermal power stations are fitted with air pollutant emission control technologies. Conversely, burning biomass in the residential sector, for cooking and heating, is often among the largest sources of air pollutant emission, whereas the CO_2 emissions from this source are biogenic, and are accounted for under the Forestry and Other Land Use Change sector. Developing more advanced methods that meet higher methodological tiers would provide greater resolution and accuracy for policy makers, but take time to create and implement. There is typically a process of prioritisation depending on the needs of those policy makers to select improvement tasks and to create a balanced prioritisation system.

For some advanced methods of some major sources of air pollution, greater data resolution on technologies may be required. For example, for road transportation, whilst a first order GHG emissions estimate can be derived using fuel consumption as an activity variable. For air pollution, the engine emissions standards is more important in dictating the magnitude of emissions, and so for a more accurate estimate of emissions from road vehicles, data on engine types, vehicle size and maintenance standards is required. Such a step, though, would offer the opportunity for national, regional, and local air quality managers to better interact with data and develop more effective policies.

The need for spatial detail is often needed to effectively engage with subnational governments and groups in identifying sensitive receptor groups for air pollution exposure (e.g. deprived areas).

Air quality exceedance modelling and management also **requires greater temporal resolution to data** than is offered in a typical annual emissions inventory.

The following section provides an overview of the key considerations when integrating air pollutant and GHG emission estimates for the key emissions sectors. In addition to sector-specific considerations, there are also overarching technical considerations to be considered when undertaking this integration:

Cross-cutting consideration 1

Reporting of SLCP and air pollutant emission results.

For GHGs, total emissions for different GHGs are summed and reported in carbon dioxide-equivalent emissions, by multiplying the mass emissions of individual GHGs by their Global Warming Potential (GWP). This provides a single metric to establish GHG reduction targets, and/or to compare the magnitude of emissions between countries, or source sectors. However, SLCPs and air pollutants cannot be aggregated by either using GWP or other metrics, because: i) the impacts that SLCPs have on the climate acts on substantially different timescales to long-lived GHGs like carbon dioxide, and ii) the impacts of SLCPs and air pollutants on human health depend on non-linear atmospheric chemistry that convert primary emissions into those pollutants that results in negative health impacts when populations are exposed to them. SLCP and air pollutant emissions should therefore be reported in mass units alongside emissions of GHGs to allow their magnitude to be tracked over time, health impact assessments to be undertaken and policies to be evaluated.

Cross-cutting consideration 2

Choice of methodological Tier for quantification of SLCP and air pollutant emissions.

For GHGs, the IPCC provides a hierarchy of methods that can be applied to quantify GHG emissions, i.e. Tiers 1, 2, and 3. The use of more advanced methods (Tier 2 or 3) should be worked towards when an emissions source is identified as key. The IPCC Guidelines outlined how a Key Category Analysis can be undertaken to identify which sources would benefit from a more advanced method. A similar Key Category Analysis should be undertaken for SLCPs and air pollutants as well as this may highlight other sources for which a more advanced method is more appropriate given the magnitude of the source.

Cross-cutting Issue 3

Applicability of existing methodologies and emission factors.

For GHGs, the IPCC Guidelines have been developed to be globally applicable. The methodologies in the EMEP/EEA Guidebook should be globally applicable, but some of the emission factors and other default data may only be representative of European conditions. Users should therefore use default emission factors from the EMEP/EEA guidebook with caution if applying them to other contexts. In some cases, higher tier methods that include more components, such as technology-specific emission factors, may be easier to convert to local conditions but would also include the need to collect this data regarding the region to which it is applied.

Figure 4 below provides an overview of the data flows and links for integrating air pollutant and GHG estimation into reporting and decision maker advice. This illustrates the common information sources (e.g., national statistics and other sector specific activity data) as well as the additional data needed to support policy makers and meet national and international air quality and climate change reporting requirements.

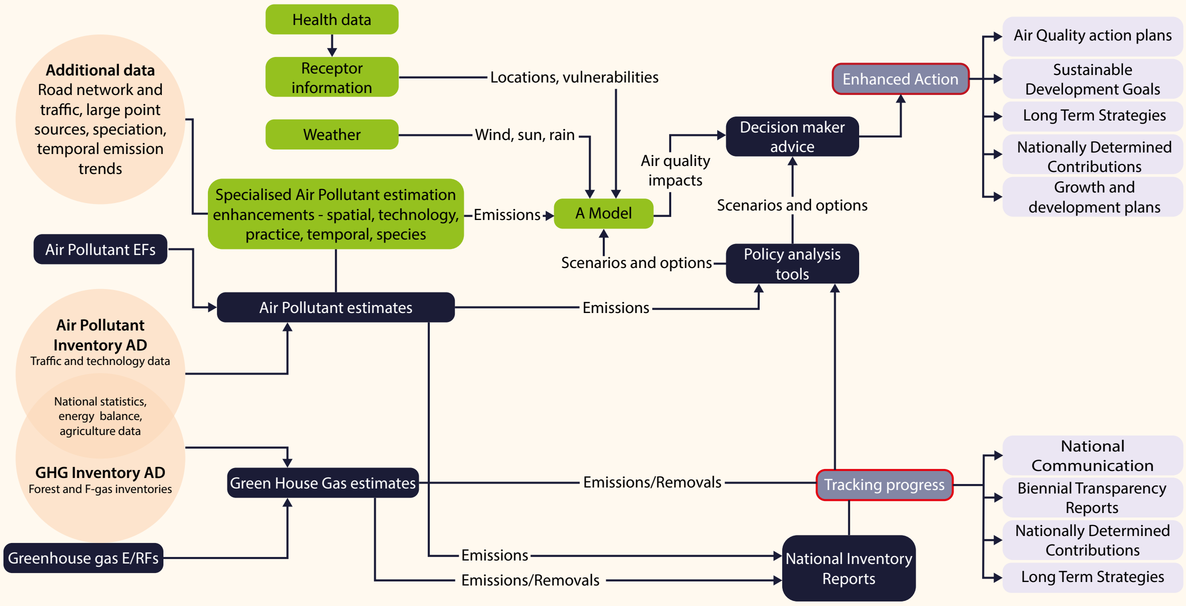


Figure 4: Overview of data flows using air pollutant and GHG information.

Sector-specific guidance on integration of SLCPs, air pollutants and GHG emission quantification

As outlined above, the integration of air pollutants and GHGs into emissions inventories is facilitated by harmonised data flows and methodologies covering GHGs and air pollutants in emission inventory guidance. A common set of activity data, and consistent methodologies with well-focused default and country specific emission/removal factors can be applied to develop integrated air pollutant, SLCP and GHG emission and removal analyses. Despite the large commonalities in the quantification of air pollutant, SLCP and GHG emissions, there are also important differences in how air pollutant and SLCP emissions are quantified in particular sectors that differ from GHGs. The commonalities and differences are summarised in the sub-sections below, and highlighted comprehensively in the **Annex**. The sector-specific guidance below focuses on highlighting the different methodologies that are available for the quantification of air pollutant emissions and shows the consistencies and differences with those that are used for estimating GHG emissions. In general, for many sectors, the Tier 1 data needs for quantifying emissions of SLCPs and air pollutants are fully consistent with the quantification of GHG emissions. To include SLCP and air pollutant emissions alongside GHG emissions using Tier 1 approaches therefore simply requires that the Tier 1 activity variable is multiplied by default emissions factors for air pollutants which are readily available from the EMEP/EEA Guidebook. The Tier 1 approach provides only a first order estimate of the magnitude of air pollutant emissions from that sector and is therefore only appropriate for quantifying national (or other geographic area) total emissions from that source. More accurate emission estimates can be obtained of national total air pollutant and other SLCP emissions through the application of higher Tier methods. Furthermore, to be able to assess the spatial distribution of air pollutant and other SLCP emissions, higher Tier methods are often necessary.

Photo: © UN Photo/Kibae Park

Table 1: Summary of sector-specific activity data needed to quantify GHG and air pollutant emissions using Tier 1 methodologies.

SECTOR	GHG REQUIREMENTS	AIR POLLUTANT REQUIREMENTS
Energy		
1A – Stationary combustion	Fuel consumption split by sector and fuel type	
1A – Mobile combustion	Fuel consumption split by transport mode and fuel type	
1B – Coal mines	Raw coal production, number of coal mines	
1B – Oil and gas	Oil and gas production statistics	
Industrial Processes and Product Use		
2 – Industrial processes	Production statistics	
2 – Product use	Product sales	
Agriculture, Forestry and Other Land Use		
3 – Agriculture	Livestock populations, typical livestock mass, use of manure management systems Fertiliser application and nitrogen applied to soils Application of lime Application of urea Crop Production	
4 – Land Use, Land Use Change and Forestry	Areas of different land types Production import and export of solid wood products Biomass burned	
Waste		
5 – Waste	Solid waste disposed Organic waste composted Waste incinerated or open burned Organics in wastewater	

The following sections outline key considerations to quantify SLCP and air pollutant emissions alongside GHGs, for specific sectors. The sector-specific guidance does not replicate the description of emission inventory methodologies, which are readily available from the IPCC Guidelines and EMEP/EEA Guidebook. Rather, the sub-sections focus on specific aspects of quantifying SLCP and air pollutant emissions that practitioners should consider when integrating SLCPs and air pollutants into their GHG emission assessments.

Energy

Photo by Kindel Media on Pexels

Energy

Emissions in the energy sector can be categorised as either fuel combustion or fugitive emissions, such as leaks or intentional flaring of gases) associated with the production of fuels.

For GHGs, a Tier 1 approach uses the quantities of fuel burned in different combustion processes as the main activity variable, combined with emission factors based on the typical carbon content of relevant fuels (for CO_2 emissions) and combustion conditions (to estimate CH_4 and N_2O emissions). A Tier 1 approach uses default emission factors specific to particular energy subsectors. A Tier 2 approach involves determining country-specific emission factors for particular fuels and subsectors, whilst a Tier 3 approach further disaggregates energy subsectors on the basis of the type of combustion, operating conditions, and maintenance standards to determine the GHG emissions. Typically, fuel combustion is broadly categorised as stationary and mobile. Examples of stationary combustion include power stations and domestic fuel use. Mobile fuel combustion includes transportation and off-road mobile machinery.

Tier 1 methods for fugitive emissions instead tend to use quantities of fuels produced, such as amounts of coal mined or amounts of oil produced and stored. The GHG emission component of fugitive emissions are primarily CH_4, an SLCP and so development of more advanced methodologies would dramatically improve understanding of the impact of fuel production on climate change.

The general, **Tier 1 approaches for air pollutants available are consistent and conformable with Tier 1 GHG methodologies.** The EMEP/EEA Guidebook Tier 1 methodologies multiply a fuel consumption activity variable by a fuel-specific emission factor, with default values provided. This provides a straightforward approach to quantifying and air pollutant emissions alongside GHGs in the energy sector, using the same activity data as is used for GHG emission estimation. The application of the Tier 1 methodologies for air pollutants however, have important limitations that should be acknowledged and considered when undertaking an integrated emission assessment. These limitations include:

- For air pollutants, the technology and operating conditions within which fuel is combusted are a large determining factor in the magnitude of emissions of specific pollutants. Therefore, the accuracy and precision of air pollutant emission estimates will be substantially improved if higher Tier methods (more country or installation specific emission factors), that account for the technology within which the fuel is being combusted is taken into account.

- For air pollutants, ‘end of pipe’ emission control technologies may be available, but a lack of detail on the technologies that are used can make it difficult to assess the emissions from a given source accurately.

The EMEP/EEA Guidebook provides higher Tier methods for the quantification of air pollutant emissions that can improve the robustness of the magnitude of emissions, as well as better facilitate the spatial allocation of emissions, and assessment of particular policies and measures. Tier 2 methods for quantifying emissions from fuel combustion typically involve using activity variables that disaggregate activity in the energy subsector not only by fuel, but also by the specific technology that the fuel is combusted within. For example, Tier 2 air pollutant methods for road transport require a more sophisticated understanding of the fleet composition in terms of vehicle types, age, maintenance, and engine emissions standards met.

Whilst this information is needed to improve estimates of CH_4 and N_2O in GHG emissions estimates from the road transport sector, the relative improvements in accuracy of using data of greater resolution is far less than the improvements in accuracy that this data would have on air pollutant emissions estimates. Data that can help move to a higher Tier methodology is often recorded by a combination of vehicle registry agencies (for fleet numbers) and road vehicle movement surveys to establish the relative mileage driven by each age, type, and size profile of vehicle.

Biomass combustion can produce large air pollutant emissions at point of combustion. In GHG inventories, the CO_2 emissions associated with the combustion of biomass is not accounted for in the energy sector emissions. They are considered biogenic and would be included in the Forestry and Other Land Use (FOLU) sector. In the FOLU sector, the loss of biomass from forests and other land use types for fuel wood is combined with other losses of biomass, as well as biomass gains in different land use types to quantify the net change in CO_2 emissions, as the balance between carbon sources and sinks in forests and other land use types. For other GHGs, such as CH_4 and N_2O, their emissions are accounted for within the energy sector emissions and are associated with the sector where the biomass is burned. The same approach should be taken with air pollutants. The emissions associated with the combustion of biomass of air pollutants and SLCPs in many countries, especially low and middle-income countries, can make a major contribution to negative household and ambient air pollution. Tier 1 methods of emissions from biomass burning follow the same principles as for fossil fuel combustion, with quantities of fuel used the key activity variable, and the emissions are allocated to the subsector where the biomass is being consumed.

Photo by Cuttersnap on Unsplash

Composition of the fuel is important to determine emissions of sulphur dioxide: For SO_2 emissions specifically, it is not just the type of fuel, or the technology that burns it that is important, the ‘fuel quality’ or composition must be known in order to quantify SO_2 emissions from burning different fossil fuels. The fuel quality, i.e. the quantity of sulphur contained within a fuel (generally described in parts per million) varies substantially across the globe, from ~10 ppm in many high-income countries, to 1000’s ppm in some countries with high sulphur fuels.

Table A1 in the Annex provides further details on the specific considerations in energy subcategories, in addition to the general considerations outlined above. These sub-categories include energy industries, manufacturing and construction industries, residential and commercial sectors, transport and agricultural energy consumption.

Data requirements for higher tier methods for road transport for GHGs, air pollutants, and SLCPs

Road transport is often a key source of emissions for GHGs and air pollutants. In many places, monitoring of vehicle movements is irregular or absent entirely and establishing an accurate, integrated inventory is a major challenge. To estimate emissions from road transport using a higher tier methodology, a range of data sources need to be collected and cleaned. These include:

Fleet composition: information on the relative proportions of vehicles split by type (e.g., car, HGV, bus, etc.), size profile, age, and engine emissions standard. Note as the EMEP/EEA Guidebook is developed for the European market, emission factors are based on EURO standards met. This data is typically stored by vehicle registry agencies.

Vehicle-kilometres driven: information on how far each of the categories defined in the fleet composition drive per year is also required. In general, newer vehicles tend to be driver further than older vehicles. This data can be collected through periodic vehicle monitoring surveys or records of mileage from annual vehicle services/registration documents.

Fuel consumption: An important calibration step of any method that builds estimates in a bottom-up manner is to ensure that the fuel used total matches those implied by national energy balances. Emissions of GHGs and air pollutants should be scaled so that the implied fuel consumption matches that of the energy balance estimates for the road transport sector.

Functionality of catalytic converters: Vehicles that meet certain engine emissions standards having catalytic converters installed. Assumptions are needed, based on the maintenance and upkeep of vehicles, on whether these catalytic converters are operational. In particular, in some countries where fuel quality is not sufficient, these catalytic converters are removed and emission factors associated with the engine emissions standard of the bought vehicle no longer apply. This assumption is usually based on expert judgement from analysts in transport ministries or inventory teams.

Cold start conditions: When a car engine has been initially ignited and engine temperatures are cool, the efficacy of aftertreatment technology is low. Assumptions, typically made by inventory teams and/or analysts from transport ministries, on the relative distance driven with cool engines is required for some higher tier methodologies.

A range of emissions inventory tools are available for estimating emissions of GHGs and air pollutants including COPERT and HBEFA. Note that, as with the EMEP/EEA Guidebook, these have been developed primarily for a European setting and caution should be used when interpreting the results of these tools. Each contain a suite of their own default values should information be unavailable otherwise.

SECTION 3

Industrial Processes and Product Use (IPPU)

Photo by Ioana Baciu on Unsplash

Industrial Processes and Product Use (IPPU)

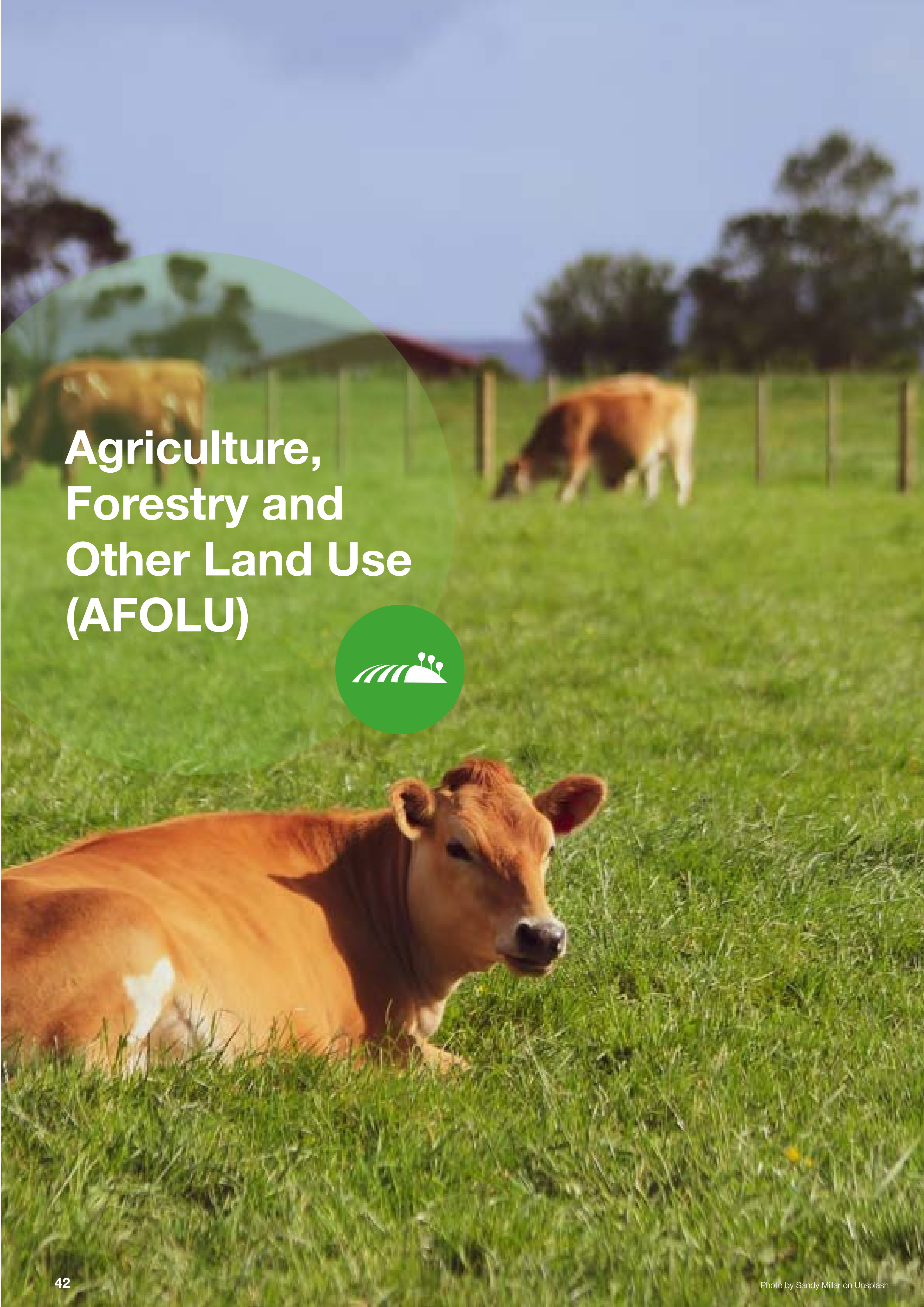
Emissions in the Industrial Processes and Product Use (IPPU) sector originate from a huge range of activities, which vary considerably from one country to the next.

Tier 1 GHG emissions estimates tend to be based on levels of production for large emitting industries, such as the mineral, chemical, and metal industries, and the sales of products as a proxy for product use. Default emission factors are available on a process-specific basis that characterises the typical emissions of industrial processes and the leakage rates of Hydrofluorocarbons (HFCs) and other fluorinated gases during product use, such as from refrigeration. In many cases, the activity data requirements for a Tier 1 methodology outlined in the EMEP/EEA Guidebook for air pollutants is the same. Note that there are some additional categories that must be included to create a complete air pollutant emission inventory, such as emissions from quarrying. The calculation of air pollutant emissions sometimes requires more detailed data than GHG calculations because the specifics of technology, processes and abatement measures have a significant impact on air pollutant emissions, particularly when using higher Tier methodologies.

For countries with an active industrial sector, emissions from facilities can dominate the inventory. As such, more robust industrial reporting systems (e.g., National Pollutant Release and Transfer Registers (PRTR)) are often developed connected to industrial emissions regulations. These systems can support accurate inventory estimates in the industry sector, particularly when this reporting mechanism considers data requirements for all GHGs and air pollutants. As described in **Section 7**, in South Africa, for example, a combination of systems and reporting platforms have advanced understanding of the emissions of GHGs and air pollutant emissions from industrial sites. The development of the South African Emissions Licensing and Inventory Portal (SAAELIP) to manage the reporting of large industrial site emissions means that it can be directly used in the calculation of air pollutant inventories from the industrial sector (both combustion, reported under the energy sector, and process emissions reported under IPPU). SAAELIP comprises a system to quantify the emissions by pollutant and then a management system for the permitting and licensing of individual sites. Which can then be readily aggregated and reported by the relevant ministerial department on an annual basis. Providing citizens and policy makers with a strong evidence base of emissions from the industrial sector. In general, any existing permitting mechanisms that require reporting by individual sites can be broadened to include a wider suite of GHGs and air pollutants, enabling more accurate quantification of emissions from the sector.

There are some category estimates that may be directly transferable from GHG inventories to air pollution inventories. Indirect CO_2 emissions from solvent use are often reported in GHG inventories, which are calculated from Non-methane Volatile Organic Compounds (NMVOC) emissions. As such, if these are reported, it is likely that data concerning NMVOC emissions are already available and can be used in the air pollution inventory.

Table A2 in the Annex provides specific guidance for IPPU for IPPU sub-sectors, including mineral, chemical, food and beverage, metal production and solvent production and use. production and use.



Agriculture, Forestry and Other Land Use (AFOLU)

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Agriculture, Forestry and Other Land Use (AFOLU)

Emissions of GHGs and air pollutants in the Agriculture, Forestry and Other Land Use (AFOLU) sector arise from a variety of sources, including enteric fermentation of livestock, management of livestock manure, application of fertiliser to soils, and other crop production practices including residue burning.

The EMEP/EEA Guidebook provides comprehensive methodology at both Tier 1 and Tier 2 level for estimating these emissions, and generally aims to be as harmonised as possible with IPCC Guidelines. **Table A3** in the Annex provides a source-by-source assessment of the data and methods required to integrate air pollution and SLCP emissions into agricultural GHG inventories.

Agriculture is generally a notable source of methane, NMVOCs and ammonia in national inventories. Methane is one of the most significant GHGs produced by the agricultural sector, and as such the IPCC Guidelines provide comprehensive methods to estimate this. Emissions of ammonia arise from the same sources as N_2O emissions, and therefore generally similar activity data can be used in Tier 1 and Tier 2 calculations (livestock numbers, nitrogen excretion, organic and inorganic fertiliser application to soils). In addition, by calculating NH_3 (and NO_x) emissions directly, this can feed back into improving estimates of indirect N_2O emissions in the GHG inventory. In some cases however, more detailed activity data is required to estimate NH_3 emissions accurately, or to allow the impact of mitigation measures to be captured in calculations. NMVOC emissions from livestock can also be estimated with the same underlying activity data as GHG emissions for Tier 1 and Tier 2 (number of animals, feed intake), but some additional data on silage feeding is required.

There are some sources of air pollutant emissions which have no parallel in the GHG inventory, including emissions of NMVOCs from crop canopies, particulate matter from field operations (harvesting, cultivation) and hexachlorobenzene (HCB) from pesticide application. For NMVOCs and particulate matter, the activity data required is already needed for GHG calculations, whereas additional data is required for emissions from pesticide application. Equally, there are no air pollutants arising specifically from land use change processes (loss or gain of carbon in different pools), except for biomass burning.

Table A3 provides specific guidance for the integration of air pollutant and SLCPs with GHG emission estimates for agriculture sub-categories, including livestock and crop production emission sources.

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Waste

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Waste

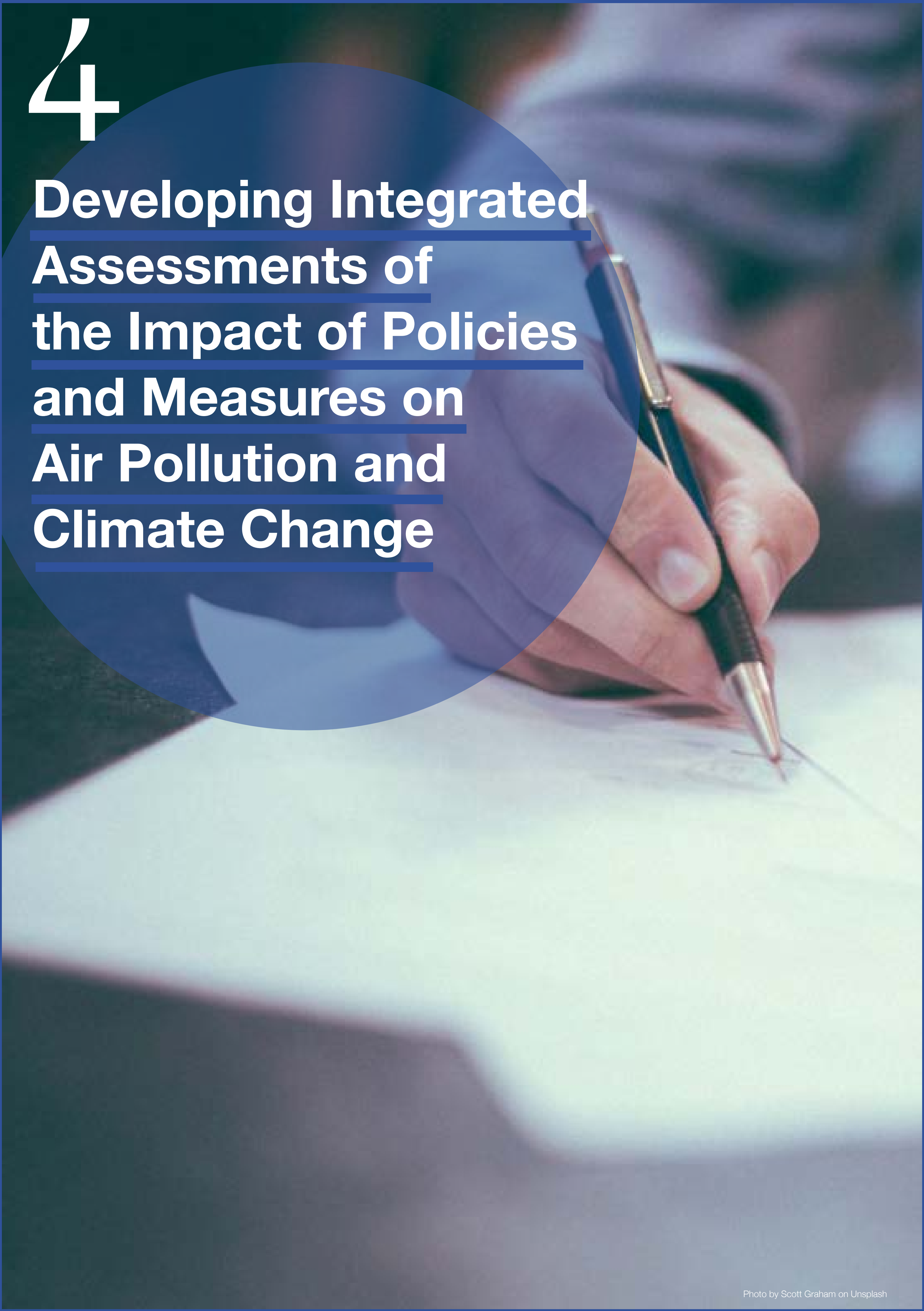
Emissions in the waste sector are typically a greater consideration for the main GHGs in comparison to many air pollutants. For some air pollutant types, however, such as heavy metals and persistent organic pollutants (POPs), waste is of greater importance.

Methane emissions from landfill sites can be a large contributor to GHG emissions inventories, produced through the anaerobic breakdown of organics in the waste. However, in countries that have high levels of waste incineration and open waste burning, emissions of GHGs, including biogenic and non-biogenic CO_2, air pollutants, and SLCPs would be expected to be larger. Methodologies in terms of activity data and emission factors for combustion sources within the waste sector are often poorly defined and carry high degrees of uncertainty. Solid waste management by biological methods, such as composting and anaerobic digestion, along with wastewater management processes can emit significant amounts of direct GHGs (primarily as methane) along with more negligible air pollutants emissions (including NMVOCs, NH_3).

Typical Tier 1 methods in the waste sector rely on waste generation data, whether household, industrial, clinical, or other forms of waste, wastewater generation, and amounts of waste burned. Default emission factors are available, but the use of regional or country-specific emission factors is much preferred due to differences in waste composition, treatment pathways, and emissions management practices. For example, solid waste management policy has tended to prioritise the diversion of waste from landfill to other systems where there are reduced wider environmental impacts (e.g., to land and water) as well as reduced GHG impacts. More modern technologies such as incineration with energy recovery are becoming more prevalent and favoured within a circular economy model. Such waste sector policies and measures as well as waste reduction, re-use and recycling schemes may have further, often cross-sectoral, impacts. One example is where recycling reduces GHG emissions in other sectors by replacing virgin materials with recycled materials. The divergence of solid waste between treatment options may also influence activity data across various national and international (in the case of waste exports) transport modes.

Table A4 in the Annex provides specific information on the integration of air pollutants and SLCPs with GHG emission estimates for both solid waste disposal, waste incineration and wastewater.

Photo by Tom Fisk on Pexels



4

Developing Integrated Assessments of the Impact of Policies and Measures on Air Pollution and Climate Change

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Key messages

1 **The key approach to extend an historic emission inventory to an evaluation of policies and measures is the development of future scenarios that can assess how emissions are likely to change with and without the implementation of a policy or measure.**

2 **An evaluation of the impact of GHG emission reductions from policies and measures can be simply extended to an integrated assessment of air pollution and climate change mitigation through the addition of air pollutant emission factors within the assessment modelling framework.**

3 **The inclusion of air pollutant emission factors within the evaluation will allow air pollutant emission reductions from specific policies and measures to be evaluated, a prerequisite to quantify the air pollution health benefits from different policies and measures.**

4 **At the sectoral level, there are a large number of specific policies and measures whose implementation is likely to achieve both reductions in GHG and air pollutant emissions.**

5 **There are also policies and measures where there may be trade-offs between air pollution and climate change, such as biomass electricity generation, or natural gas-powered transport. Integrating assessment of the impact of policies and measures on air pollution and climate change allows these trade-offs to be identified, and compensated for.**

Evaluation of policies and measures builds on an emission inventory and quantifies the emission reduction potential of mitigation measures. An integrated approach to this evaluation, incorporating GHGs and air pollutants would allow for the identification of common sources of each and the mitigation measures that would lead to the greatest overall benefit in terms of emissions reduction. It can also highlight mitigation measures where there may be trade-offs, where implementation may reduce emissions of GHGs but have a limited or even negative impact on emissions of air pollutants, or vice versa.

The evaluation of policies and measures is routinely undertaken both in climate change planning and in air quality management. For example, they are used in developing GHG mitigation strategies and quantifying targets in NDCs, or to illustrate compliance with multinational air quality legislation such as the EU's National Emissions Ceiling Directive. As with emissions inventories, there are substantial overlaps in the data requirements and methods needed to evaluate the impact of policies and measures on GHG, air pollutant, and SLCP emissions.

An integrated policy and measure evaluation approach offers a number of opportunities:

Ensures that the full impact of climate policies and measures is quantifiable. Most policy and measure evaluations undertaken within climate change planning assess only GHGs. However, SLCPs that are not GHGs, like black carbon, also have a positive (warming) radiative forcing. Other air pollutants, including organic carbon and sulphur dioxide, have a negative radiative forcing, i.e. increases in their emissions cool the atmosphere. The relative changes in emissions of all these substances will determine the overall impact of a policy or measure on climate change. Accounting for the emissions of the full suite of GHGs, SLCPs and air pollutants ensures that the overall benefit of a policy on climate change can be more accurately quantified. Note that sulphur dioxide and organic carbon emissions have other detrimental impacts on the environment and increasing their emissions should not be considered a viable action to mitigate climate change.

Identify the reductions in local air pollutant emissions from actions that also reduce GHGs. An integrated evaluation of policies and measures can show how the most health-damaging air pollutants, such as particulate matter and nitrogen oxides, are reduced when specific policies and measures are implemented. This can be used to show the local benefits that can be achieved from implementing climate change policies, for example. If spatial data is available to support this, then dispersion models can be used as a next step to quantify the impact of policies and measures on air pollutant concentrations and used to show progress towards meeting World Health Organisation (WHO) or national standards on pollutant concentrations.

Enables the quantification of the health benefits that can result from the implementation of policies and measures designed to reduce emissions (described in **Section 5**). In order to quantify the health benefits from reduced air pollution exposure that could result from the implementation of climate change, air pollutant, or SLCP policies and measures, it is essential to quantify the change in air pollutant emissions required and the sectors targeted.

This section provides a brief overview of the general approaches that can be taken for the development of an evaluation of policies and measures, and then highlights key considerations when undertaking an integrated assessment of the impact of policies and measures on air pollution and climate change mitigation.

Overview of approaches for assessment of policies and measures

Existing guidance on evaluation of policies and measures

For climate change mitigation planning, there is no prescribed methodology for evaluating and quantifying the impact of policies and measures on GHG emissions required for reporting in either National Communications or BTRs. This is to reflect the variability in mitigation measures developed in response to the bespoke situations that each country will face in its path to decarbonisation. This, therefore, leads to variation in the methodologies used and in the way outputs are communicated through climate change reporting. The resources shown in Table 2 on the following page therefore, provide possible approaches, tools, and methods which can effectively evaluate policies and measures in terms of their impacts on GHGs, SLCP and air pollutant emissions. It is the responsibility of the evaluator to identify the most appropriate method for the evaluation of particular policies and what information to extract in order to communicate the results.

The case studies in **Section 7** provide details on some of the tools being utilised elsewhere for different sectors. For example, Colombia, and South Africa use the “Low Emissions Analysis Platform”(LEAP) with its integrated benefits calculator as a tool to quantify the impacts of policies on SLCPs. Whilst on a city-level, Santa Rosa in the Philippines uses the transport model “Transport Emissions Evaluation Models for Projects” (TEEMP) which allows for quantification of SLCP emissions from the road networks to demonstrate the impact of transport policies on greenhouse gas and major air pollutant emissions. Some countries, such as Norway, have developed their own tools to look at the impact of policies on GHGs and SLCPs on emissions, human health, and SDGs.


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Table 2: A selection of key resources providing guidance on the development of evaluations of policies and measures on air pollution and climate change

Title	Description
European Monitoring and Evaluation Programme / European Environment Agency (EMEP/EEA) Emission Inventory Guidebook 2019 Part A Chapter 8: Projections	Overview of methods and approaches for developing projections of air pollutant emissions (including with implementation and without implementation of mitigation measures).
Opportunities for Increasing Ambition of Nationally Determined Contributions through Integrated Air Pollution and Climate Change Planning: A Practical Guidance document	Overview of approach to integrated assessment of air pollution and climate change mitigation, including summary of key policies and measures that can simultaneously reduce air pollutants, SLCPs and GHGs.
Mitigation Goal Standard: An accounting and reporting standard for national and subnational greenhouse gas reduction goals	Guide from the GHG Protocol on methods and approaches to develop assessments to define GHG mitigation targets.
Low Emissions Analysis Platform (LEAP)	Tool that has been widely applied to conduct integrated air pollution and climate change mitigation assessments.
Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS)	Tool that has been widely applied to conduct integrated air pollution and climate change mitigation assessments
Global Livestock Environmental Assessment Model (GLEAM)	Tool for assessing emissions from the livestock sector, including GHGs and SLCPs.
Solid Waste Emissions Estimation Tool (SWEET)	Tool for assessing emissions from the waste sector, including GHGs, SLCPs and air pollutants.
GHG Abatement Cost MOdel (GACMO)	Tool which can be used to evaluate policies and measures and their impact on GHG emissions, but not air pollutants.
ICAT Policy Assessment Guides	Guides on how to evaluate climate change mitigation policy for specific sectors, or how to integrate overarching topics (e.g. sustainable development) into evaluation of climate change policies.

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Scenarios as key tool for policy and measures evaluation

When undertaking an evaluation of policies and measures to assess their emission reduction potential, the key approach used to make that assessment is **scenario analysis**. Under the ETF, countries are required to report emission projections and should distinguish projected emissions "with measures" and "without measures" and may add a scenario "with additional measures".[1] Scenarios illustrate how emissions are projected to change into the future, whether over the short-, medium-, or long-term. Different scenarios with different sets of policies and measures included can be used to quantitatively show the difference in emissions of GHGs, air pollutants, and SLCPs. They are typically used to develop policy and measure strategies either on a national level inclusive of all emissions sources, or on an individual sectoral basis. The results from scenario analysis, in terms of GHG emission projections with and without measures, are to be submitted in Biennial Transparency Reports beginning in 2024.

Within climate change planning and air quality management, there is often different terminology applied to the development of scenarios used in the evaluation of policies and measures. However, the broad approaches and purpose to the development of alternative emission scenarios is the same.

Within climate change planning, the scenarios developed are often categorised into two groups:

(i) Baseline scenarios, which may also be referred to as a business-as-usual, or reference scenario, and
(ii) Mitigation scenario(s), shown in Figure 7.

The primary purpose of the baseline scenario within climate change planning is to provide a reference against which the effectiveness of mitigation scenarios can be compared. As a result, the baseline scenario is often developed to represent the likely future progression of emissions without implementation of any climate-related policies and measures.

A **baseline scenario** is often developed by projecting measures of activity in different sectors based on specific proxies that are considered appropriate for that sector. These can include demographic and economic variables such as population and Gross Domestic Product (GDP). Establishing the appropriateness of a proxy is assessed either through quantifying correlation between activity and proxy across the historic inventory or through the best judgement of sector experts. The output from the baseline scenario are emission estimates in future years typically for all sectors, without implementing any policies or measures. Some versions of a baseline scenario also include the impact of policies and measures that have already been implemented as data availability may preclude the complete differentiation of existing emissions with and without these measures. The principle remains though: the baseline scenario is developed to aid comparisons and to quantify the impact of future policies and measures.

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[1] Decision 18/CMA.1: Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement, chapter III, section F.

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Mitigation scenarios then evaluate how implementation of specific policies and measures impacts emissions in future years, compared to the baseline scenario. Policies and measures that can be evaluated can include a wide range of different types of measures, such as those summarised in Figure 5 on the next page. They include changes in technology (e.g., switching to more efficient biomass cookstoves), changes in fuels (e.g., switching from internal combustion engine vehicles to electric vehicles), changes in behaviour (e.g., greater use of public transport), energy efficiency (e.g., minimum energy performance standards for appliances), or switching to diets with lower climate impacts, or economic measures such as carbon taxes. When developing an evaluation of policies and measures, it is necessary that each of these mitigation measures is defined with a specific target (e.g., 500,000 households switch from cooking using biomass to cooking using LPG) and timeline for its achievement. This provides the quantitative basis to assess how a scenario in which a measure is implemented differs from a basis, and allows the variables identified within the modelling to be changed to reflect the implementation of this measure.

Within air pollution planning and reporting, similar approaches are taken when developing projections, albeit with some small differences in terminology. The CLRTAP requires countries to report emission projections. The EMEP/EEA Guidebook includes a chapter on emission projections to facilitate consistency and comparability of scenarios between countries. A scenario called ‘Without Measures’ (WOM) is similar to the baseline scenario and represents the projected emissions without the implementation of any policies and measures. Two mitigation scenarios are then required for reporting air pollutant emission projections under the CLRTAP: With Existing Measures (WEM) and With Additional Measures (WAM). These distinguish between scenarios with the implementation of policies and measures that have already been legislated (WEM), and those that are not yet adopted by national Government (WAM). However, the basic approach to the evaluation of policies and measures, and the construction of the mitigation scenarios is the same as for climate change planning. The EMEP/EEA Guidebook approach simply represents a different way of aggregating packages of mitigation measures into combined mitigation scenarios. Figure 5 illustrates the distinction between the WOM, WEM and WAM scenarios according to the EMEP/EEA Guidebook.

The development of scenarios that evaluate how emissions change for different future assumptions provides the basis to also evaluate other impacts, such as health impacts from reduced air pollution as described in **Section 5**. The case studies in Colombia, Ghana and the Philippines, and in **Section 7** provide some examples of scenarios developed to estimate future emissions in 2030 and 2040 to evaluate the impact of implementation policies and measures.

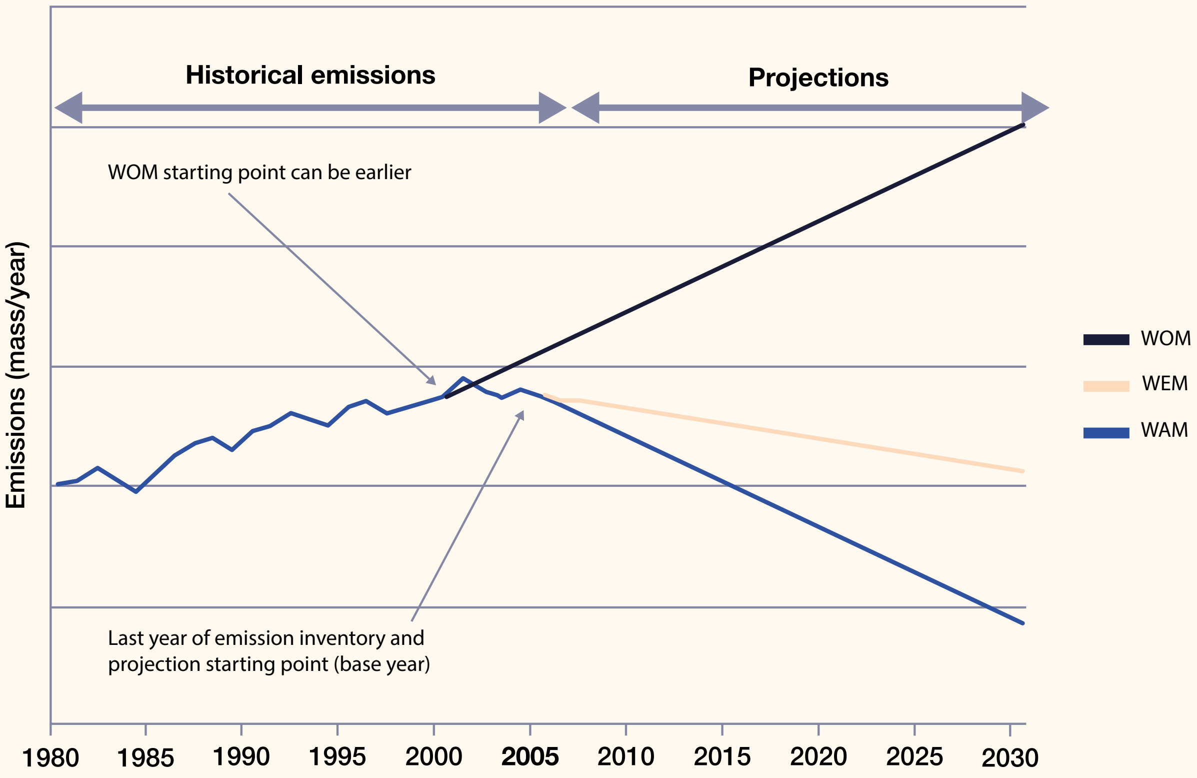

Figure 5: Example graph showing distinction between historic emissions, and future projections without measures (WOM), with existing measures (WEM), and with additional measures (WAM) used for air pollution projection reporting under Convention on Long-Range Transboundary Air Pollution (CLRTAP). Source: EMEP/EEA (2019).

Approaches aimed at evaluating individual policies and measures

The modelling of emissions of GHGs, SLCPs and air pollutants involves the multiplication of activity variables (e.g. gasoline consumption in the transport sector) by emission factors (e.g. kg CO_2 emitted per litre of gasoline consumed). This relatively simple concept is made more complicated by the level of detail by which it is possible to define activity variables and their corresponding emission factors. Activity variables can be defined for entire sectors or broken down to more specific sub-sectors and sources to increase the specificity of emission estimates (see **Section 3** for further details).

Whether developing an assessment of policies and measures to quantify greenhouse gas emission reductions, or reduction in air pollutant emissions, the process, methods and approaches are different to the accounting of historic emissions from different sectors and sources, and often requires the use of a different set of tools and methods to undertake. For both evaluation of policies and measures, and historical emission inventories, activity variables are multiplied by emission factors. However, the level of disaggregation in activity data necessary to evaluate some policies and measures may need to be greater than for historical inventories to allow the variables affected by the implementation of policies and measures to be evaluated.

This, and other key differences in an evaluation of policies and measures compared to the development of an historical emission inventory include:

Using assumptions to project emissions rather than historic data

The development of emission projections relies on assumptions as to how activity variables that characterise sectors and sources are likely to change in the future. This contrasts with historical accounting of emissions where activity variables are based on actual data collected for each sector, such as national energy balances or statistical reports.

When developing baseline projections of emissions, it is necessary that the value of these variables be estimated for future years. This often requires that a proxy variable be identified and then used to project the activity variable in a sector in the future. Common proxy variables include population, GDP, and Value-Added GDP. In some cases, countries may have pre-existing projections of key activity variables that can be used in the development of emission projections. For example, the Ministry of Energy may project energy demand into the future as part of energy planning, and these results can be the basis for future projections of GHG, SLCP and air pollutant emissions.

Accounting for the implementation of specific policies and measures

The modelling methods for an evaluation of policies and measures should be sufficiently detailed so that the key variables likely to be impacted by the implementation of policies and measures can be changed within the baseline and/or mitigation scenarios. This can mean a more disaggregated breakdown of activity variables is necessary. It is the responsibility of evaluators to judge whether a method and data sources are appropriate for the analysis required. It is best practice to use a method and data resolution that allows for variables directly affected by policy implementation to be varied in isolation.

There are various types of modelling methods that can be applied. A common approach is Activity Analysis. An activity analysis creates future projections to evaluate policies and measures by linking changes in activity variables to proxy variables, as outlined above. Figure 6 on the following page shows an an example for the transport sector. Five potential policies or measures are shown, alongside three potential activity variables that could be used within the analysis. The first activity variable is the total consumption of fuels (e.g. gasoline or diesel) within the transport sector. In national GHG emission inventories this is often the activity variable used to estimate emissions. However, an evaluation of policies and measures in the transport sector which uses as its activity variable the consumption of gasoline and diesel is limited in its ability to assess common policies and measures in the transport sector. Switching to biofuels, or biofuel blends could be assessed with this aggregated activity variable, but switching to electric vehicles, or vehicle emission standards would be more difficult, as these measures involve the substitution of existing vehicles with different vehicles. In this instance, a more detailed activity analysis is necessary so that the penetration of vehicles meeting more stringent vehicle emission standards or electric (or other zero tail-pipe emission vehicles) can be assessed to represent the implementation of the policy and measure. An analysis in which the activity variable is the number of vehicle-km (number of vehicles multiplied by the annual average distance travelled), disaggregated by mode, vehicle type (e.g. passenger car, bus, truck) and fuel would allow fuel substitution and vehicle emission standard measures to be represented.

However, modal shift is another mitigation measure that is often applied within the transport sector. In this case, a vehicle-km activity variable makes it difficult to assess the implementation of a modal shift policy (e.g. switching journeys to public transport, walking or cycling, or switching freight from road to rail), because there is not a common metric between vehicle types. In this case, an activity variable that quantifies transport demand, such as passenger-km (number of passengers taking a particular transport mode multiplied by the average distance each passenger travels) or tonnes-km (number of tonnes of freight transport in a particular transport mode multiplied by the average distance transported) can be used to represent modal shift policies or measures (as well as the other measures shown in Figure 6 below). This example for the transport sector underlines the importance of considering the policies and measures to be evaluated when selecting the modelling method for policy and measures evaluation, which is not a consideration in inventory development.

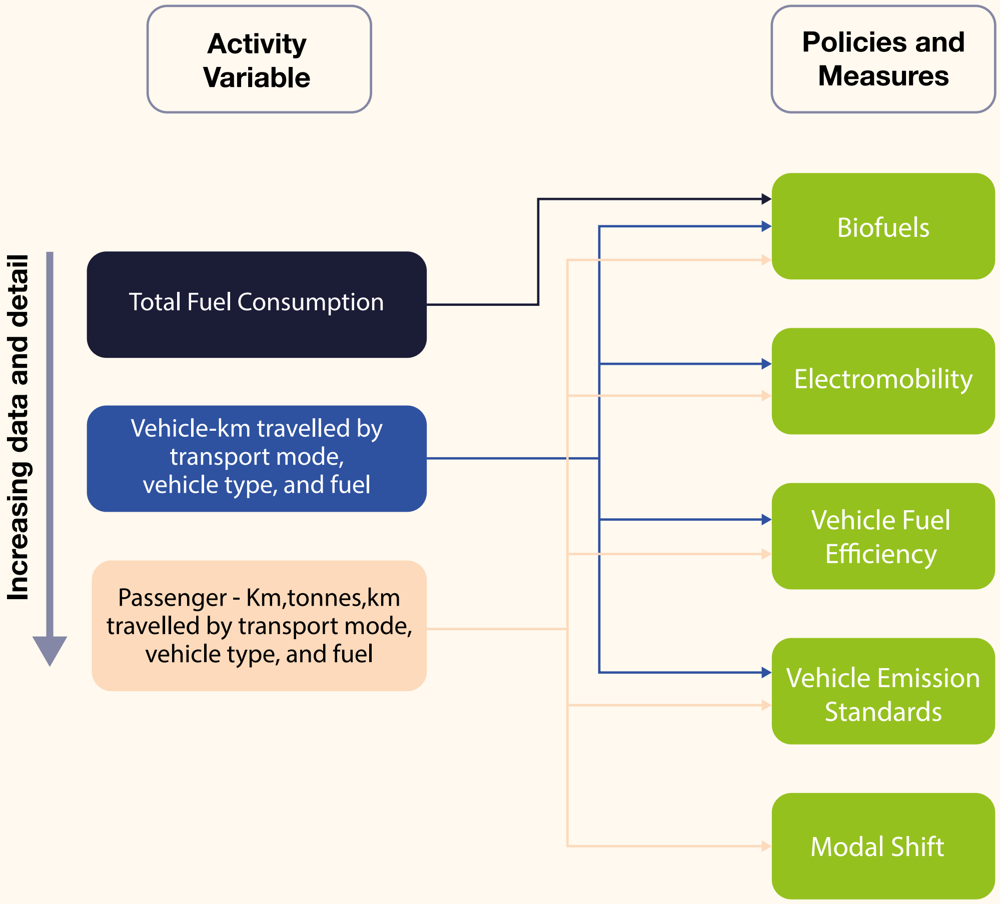

Figure 6: Example of the types of policies and measures that can be evaluated in the transport sector with different levels of disaggregation of activity variables

4

Developing Integrated Assessments of the Impact of Policies and Measures on Air Pollution and Climate Change

Photo by Max Bender on Unsplash

There are other approaches to assess the impact of policies and measures in addition to activity analysis. Stock-turnover analysis is a method for evaluating policies and measures that is well suited to assessing the penetration of new technologies into a market. An illustrative example is shown in Figure 7 on the following page. A stock-turnover analysis begins by disaggregating technologies in a particular sector in a base year (e.g. the number of vehicles meeting different Euro standards, the number of refrigerators of different efficiencies, different types of cookstoves). In future years, the change in the fraction of technologies meeting different emission or efficiency standards (or other characteristics) are determined based on the sales, and retirement rate of different technologies. This methodology provides the basis for evaluation policies and measures such as:

The introduction of vehicle emission standards (e.g. Euro VI), or introduction of electric vehicles (e.g. through subsidies, bans on internal combustion engines, or other incentives).

Minimum energy performance standards for household, or commercial appliances (e.g. refrigerators, air conditioners etc.).

Incentivisation of more efficient cookstoves or switching to cleaner fuel stoves for cooking.

Scrappage schemes to incentivise retirement of vehicles, appliances or other equipment and replacement with more efficient technology.

In all of these cases where a more efficient or lower-emitting technology is incentivised, the impact of the incentive on reducing emissions will depend on how quickly the lower-emission technology penetrates into the market. The stock-turnover approach allows the impacts of these policies to be evaluated through the adjustment of future retirement and sales rates. This type of approach typically requires a greater level of detail compared to activity analysis, in particular information on sales and retirement rates of equipment in particular sectors.

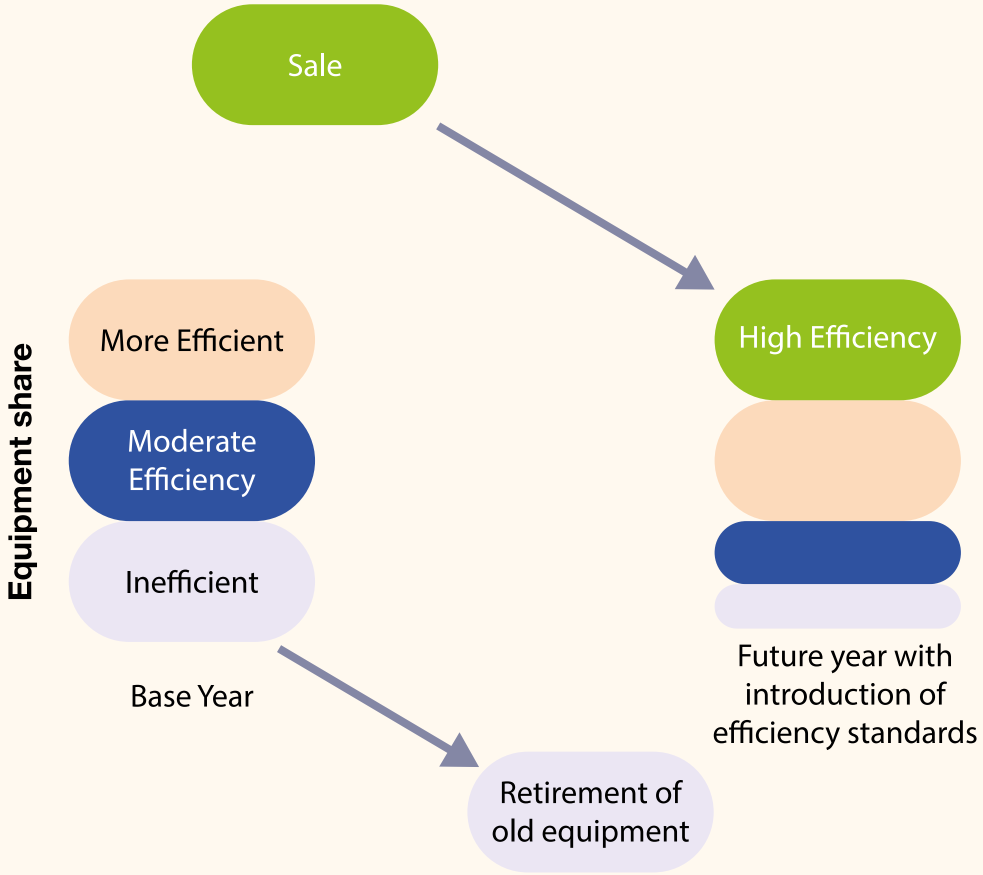

Figure 7: Illustrative example of stock-turnover analysis to assess introduction of energy efficiency standards. Diagram shows how share of equipment with different efficiencies in future years is determined by i) base year composition of equipment efficiency, ii) retirement rate of old equipment, and iii) sales of new, high efficiency equipment.

Optimisation modelling is used to minimise the cost of operating a system (typically the electricity system, or total energy system). This modelling approach can be used to assess the impact of policies and measures aimed at decarbonising the energy system. Constraints on the optimisation modelling algorithms, such as emission limits, or renewable energy targets can be used to assess how the energy system, or electricity system can be constructed to achieve those targets at the lowest cost.

There is a wide range of guidance available on different approaches to the evaluation of policies and measures (See **Table 2**), which should be used as reference in combination with this guidance on how evaluation of the impact of policies and measures on air pollution and climate change can be integrated.

Photo: © UN Photo/Michos Tzovaras

Accounting for interactions between sectors

When developing an emissions inventory, the estimation of emissions from particular source sectors are developed independently from one another. Data is collected on activity variables on a sector-by-sector basis, and the modelling methods selected are confined to each emission source sector. When developing an evaluation of policies and measures however, it is necessary to account for interactions between different emitting source sectors so the full impact of implementing a policy or measure can be evaluated. For example, some policies and measures are implemented in one sector but achieve emission reductions in another sector. This includes, for example, energy efficiency measures for appliances, which reduce electricity demand through their implementation within the residential or services sectors, but it is the electricity generation sector where these emission reductions are actually achieved.

In some cases, policies or measures can impact (positively or negatively) emissions in multiple sectors. Examples of these types of policies or measures include electromobility strategies, which reduce tailpipe emissions (or GHGs, SLCPs and air pollutants) but could increase emissions from the electricity generation sector if the increased demand for electricity from electric vehicles is generating from power stations. The diversion of waste for energy generation is another example of a policy and measure which impacts emissions from the waste sector (through diverting organic waste from landfill for example) and emissions from the electricity generation sector.

There are many different approaches, modelling methods, and tools that can incorporate the interaction between different emission source sectors in the evaluation of policies and measures. For example, energy system models account for interactions between energy demand (e.g. transport, households, industry) and energy supply (e.g. electricity generation, oil refining, charcoal production). One of the most commonly used tools for evaluation of the impact of policies and measures on air pollution and climate change is the Low Emissions Analysis Platform (LEAP).

The LEAP tool allows users to develop an energy system model to represent historic and future emissions from the energy sector. The LEAP modelling framework (shown in Figure 8 on the following page), demonstrates how an energy system model allows interactions between emission sectors to be taken into account. First, the energy demand is modelled for historic years and for future scenarios. In contrast to historical emission inventories, the activity variables for the energy supply sector (i.e. electricity demand, or oil, oil production, gas, coal, and charcoal requirements) are based on the demand for these fuels. Hence for future scenarios where the demand for electricity/fuels is expected to change (e.g. increase in response to population or economic growth, or reduce in response to policies and measures), the supply of these fuels is explicitly linked to these changes in demand. This link allows changes in emissions in the sector where a policy is implemented and within sectors that are impacted by the policy to be evaluated.

The development of an energy system model, or other modelling approach that allows for an integrated assessment of policies and measures across sectors represents an additional level of complexity beyond the compilation of an historic emission inventory. The development of historic GHG emission inventories does not require these linkages between sectors, meaning many countries do not have such a system for the evaluation of policies and measures. There is guidance available however, that can support the extension of an inventory to an integrated assessment, and some key data sources that are typically available within countries to facilitate this, such as national energy balances (**Table 2**).

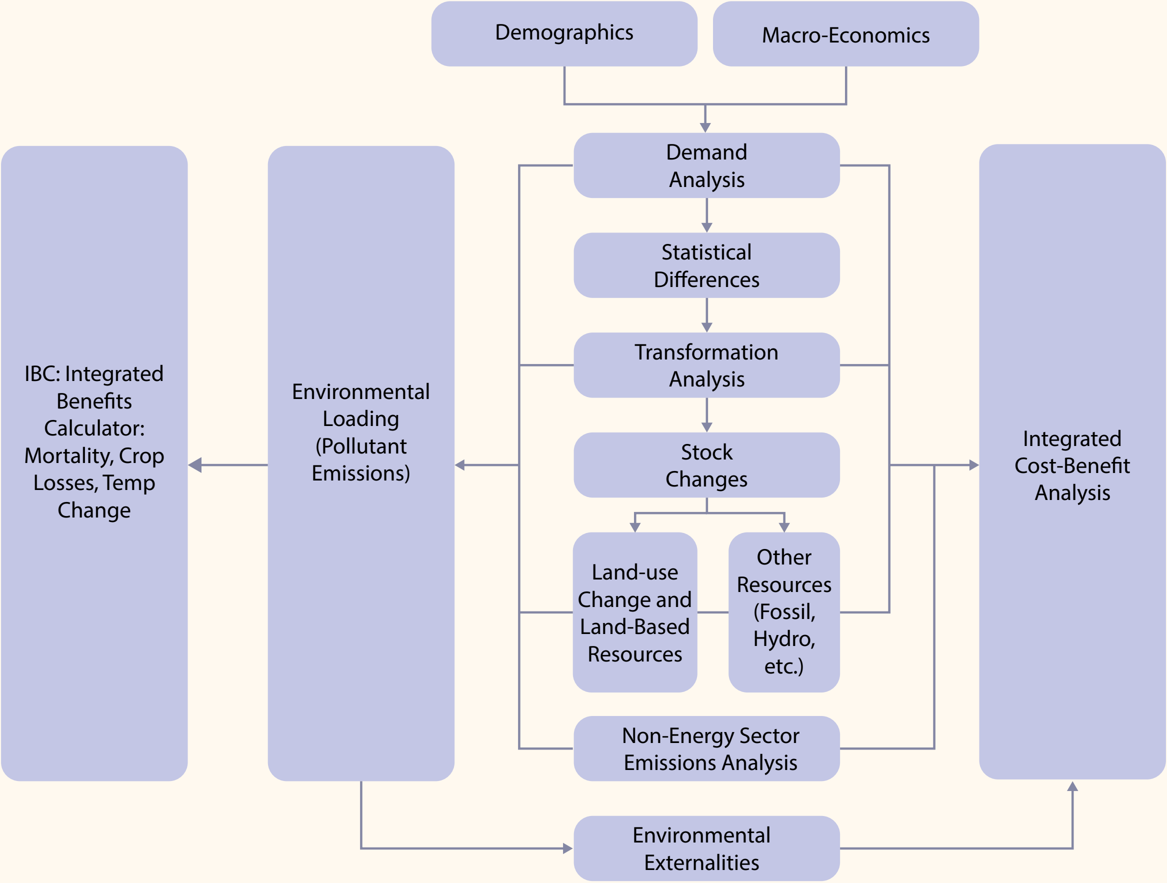

Figure 8: Representation of modelling framework for Low Emissions Analysis Platform (LEAP) tool.

Emissions target setting

The outputs from the combination of scenarios can provide the basis for establishing greenhouse gas reduction targets. Figure 9 on the following page shows a summary of the Greenhouse Gas emission reduction targets in Cote d'Ivoire's NDC (Government of Cote d'Ivoire, 2022), that is based on an evaluation of specific policies and measures. In total 39 specific policies and measures were assessed to inform Cote d'Ivoire's NDC update, including, for example, a 50% reduction in fugitive emissions from oil and gas infrastructure. The baseline scenario in Cote d'Ivoire's evaluation of policies and measures shows how GHG emissions are expected to progress in the future (up to 2030) without the implementation of the 39 policies and measures, and due to population and expected economic growth, indicates that between 2020 and 2030 GHG emissions could increase by ~30%.

Photo: © UNOPS Jason Florio, Africa

The policies and measures evaluated were grouped in different ways to illustrate different aspects of Cote d'Ivoire's climate change commitment. Complete implementation of all 39 policies and measures is expected to reduce net GHG emissions by 99% in 2030 compared to the baseline scenario. However, other combinations of measures show how this overall goal could be achieved. For example, policies and measures can be grouped by sector to show how mitigation in different sectors can reduce emissions (Table 3). Commonly in climate change commitments, policies and measures are also grouped based on whether they are unconditional (i.e. can be implemented with domestic resources) or conditional (i.e. require international support to be implemented) (Figure 9).

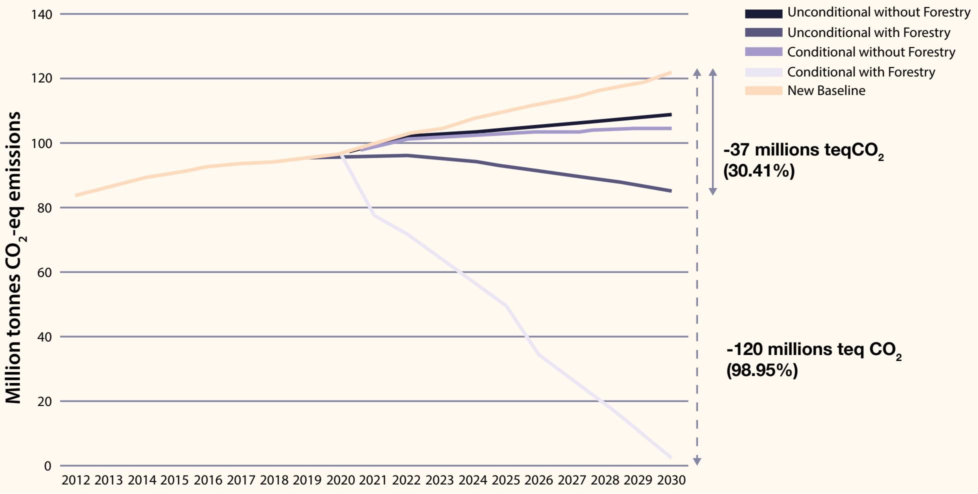

Figure 9: Greenhouse gas emission reductions expected from implementation of policies and measures included in the 2021 Nationally Determined Contribution from Cote d'Ivoire.

Table 3: Contribution of different sectors to overall Greenhouse gas mitigation targets in Cote d'Ivoire's 2021 Nationally Determined Contribution.

SECTOR	GHG EMISSIONS IN 2012 (MILLION TONNES CO_2-EQ)	BASELINE SCENARIO GHG EMISSIONS IN 2030 (MILLION TONNES CO_2-EQ)	UNCONDITIONAL SCENARIO GHG EMISSIONS IN 2030 (MILLION TONNES CO_2-EQ)	UNCONDITIONAL PLUS CONDITIONAL SCENARIO GHG EMISSIONS IN 2030 (MILLION TONNES CO_2-EQ)
ENERGY	18.00	39.91	28.51 (-28.55%)	24.88 (-37.66%)
AGRICULTURE	3.98	6.83	5.85 (-14.31%)	5.48 (-19.76%)
WASTE	3.34	6.10	5.31 (-12.96%)	5.31 (-12.96%)
FORESTRY	58.01	68.58	44.81 (-34.65%)	-34.41 (-150.18%)
TOTAL (WITHOUT FORESTRY	25.34	52.86	39.7 (-24.91%)	35.69 (-32.49%)
TOTAL (WITH FORESTRY)	83.35	121.44	84.51 (-30.41%)	1.27 (-98.95%)

Ghana - Photo by Virgl Sowah on Unsplash

Integration of air pollutants, SLCPs and GHGs in assessment of policies and measures

The approaches highlighted above, and the guidance provided in the key resources within Table 2 are applicable to the evaluation of the impact of policies and measures on GHGs, and SLCPs and air pollutants. Given the similarities in basic approach to the evaluation of policies and measures in climate change planning and air quality management, there is therefore substantial scope to develop integrated air pollution and climate change mitigation assessments which evaluate the impact of policies and measures on air pollutants, SLCPs and GHGs at the same time.

Ghana, for example, used the LEAP emission inventory and scenario analysis tool, historical emissions of SLCPs, air pollutants and GHGs and projected into the future to assess the reduction in all emissions for different mitigation strategies representing the implementation of different policies and mitigation measures compared to a baseline scenario up to 2040. It was found that if Ghana implements the measures included in its NDC, there will not only be substantial reductions in total CO_2 and CH_4 emissions, but also in BC emissions. Additional measures, not included in the NDC, focussing on SLCPs that further reduce black carbon and methane emissions were found to also reduce carbon dioxide emissions, even though they were not initially included in the decision-making process for these actions, providing a greater environmental and socioeconomic case for the implementation of these measures.

Types of policies and measures which might have impacts on air pollution, GHGs and SLCPs

Due to the substantial overlap in the major sources of GHGs, SLCPs and air pollutants, there are policies and measures in all major emission source sectors (i.e. energy, industrial processes, agriculture, forestry and other land use, and waste) that can simultaneously reduce all emissions. Some of these are summarised in Table 4 on the following page. CCAC SNAP (2019) provides a comprehensive overview of those policies and measures which have benefits for GHGs, SLCPs and air pollutants. Several of the case studies included in **Section 7** (e.g. Ghana and The Philippines) detail plans and strategies that integrate GHG, SLCP and air pollution mitigation, as well as highlighting the specific policies selected in those regions to achieve these multiple benefits.

The development of mitigation scenarios required that measures are specified with implementation targets and timelines. When integrating assessment of the impact of measures on both climate change mitigation and air pollution reductions, the consideration of measures included in Table 4 within the evaluation can help to ensure that the measures are known to lead to reductions in GHGs, SLCPs and air pollutants. In many countries, some of those measures will already be incorporated in national plans and strategies, such as NDCs. In these cases, targets and timelines could be extracted from existing plans. Where policies and measures that can have air pollution and climate change benefits are not included in plans and strategies, then their inclusion within an evaluation can demonstrate their effectiveness at contributing to both goals. Targets and timelines for these measures could be taken from neighbouring or comparable countries and contexts where these policies and measures are included in current plans, from international assessments that have provided plausible targets and timelines for these measures, or through undertaking assessment of barriers and implementation pathways, which can inform on realistic timelines for their implementation.

In addition to the inclusion of policies and measures that are known to achieve air pollution and climate change mitigation benefits, it is also useful to undertake an integrated assessment to identify some that may have trade-offs or disbenefits for climate change or air pollution. Table 4 outlines, for each sector, which measures may have these trade-offs.

Table 4: Policies and measures from CCAC SNAP (2019) that can reduce emissions of GHGs, SLCPs and air pollutants. + indicates that measure contributes to reducing a category of pollutants, - indicates that there may be some trade-offs.

Sector	Mitigation Measure	Greenhouse Gases	Short-Lived Climate Pollutants	Air Pollutants
Energy – Transport	Introduce vehicle emission standards for diesel vehicles and eliminate high emitting diesel vehicles.		++	+++
Energy-Transport	Increase percentage of electric vehicles in vehicle fleet.	+++	+++	+++
Energy-Transport	Improve public transport, and increases in walking and cycling, to reduce number of journeys taken by passenger cars.	+	+	+
Energy-Residential	Adopt more efficient fuels and technologies for cooking and heating.	+	++	+++
Energy-Industry	Replace traditional brick kilns with more efficient brick production techniques.	+	+	+
Energy-Industry	Replace traditional coke ovens with modern recovery ovens.	+	+	+
Energy-Electricity	Replace fossil fuel-based electricity generation with renewable alternatives.	+++	+	+
Energy-Demand	Implement energy efficiency standards for industry, households, commercial sector.	+++	+	+
Energy – Fossil Fuel Production	Eliminate gas flaring in oil and gas sector.	+	+	+
Energy – Fossil Fuel Production	Minimise venting, flaring and fugitive emissions from oil and gas sector.	+	+++	+
Energy – Fossil Fuel Production	Minimise methane emissions from coal mining through pre-mine degasification and recovery and oxidation of methane from ventilation air.	+	+++	+
Industrial Processes and Product Use	Eliminate HFC emissions from contained and emissive applications.	+	+++	
Agriculture	Control of agricultural methane emissions from livestock enteric fermentation and manure management.	+	+	+
Agriculture	Reduce methane emissions from rice production through intermittent aeration of continuously flooded paddy fields.	+	+++	
Agriculture	Eliminate open burning of agricultural waste.		+++	+++
Forestry and Other Land Use	Control forest and peatland fires.	+	+	+++
Waste	Minimise methane emissions from solid waste at landfills sites.	+	+++	+
Waste	Upgrade wastewater treatment plants with methane gas recovery.	+	+++	+

Key considerations

Integration of air pollutant and SLCP emission factors into scenario modelling framework.

Ensuring air pollutant and SLCP emission factors are integrated into the evaluation modelling framework is central to developing an integrated system to consider impacts on GHGs, SLCPs, and air pollution in tandem. The major sources of emission factors for use/in evaluation of polices and measures is the EMEP/EEA Guidebook for air pollutants and IPCC Guidelines for GHGs. Note that for some policies and measures, particularly those that see technological interventions and behavioural shifts, the emission factors used may require adjustment through time. For example, policies that encourage the uptake of air pollution control equipment at large industrial sites would cause a reduction in the emission factors of many air pollutants. Technology-specific emission factors are available in EMEP/EEA Guidebook for many examples as they are used for higher tier methodologies, but evaluators should try to verify the applicability of these emission factors through emissions monitoring projects and additional data collection.

Base year selection

When developing future scenarios (baseline or mitigation) to evaluate policies and measures, these projections for future years are made from a historic base year. Aligning this base year with emissions inventory outputs is important in ensuring consistency of information reported and brings confidence that any subsequent conclusions drawn from the evaluation analysis are correct and based on the latest available information. Usually, the base year is a chosen year from the emissions inventory time series.


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Sector specific considerations

Energy

In the **energy sector**, policies and measures aimed at reducing GHG, SLCP and air pollutant emissions can include energy efficiency measures, fuel switching, changes in technology, and changes in behaviour. In addition, for air pollutant, specific emission control technologies (e.g. particlulate filters to reduce PM emissions, electrostatic precipitators to reduce NO_x emissions) are available which can selectively reduce emissions of specific air pollutants. There are different types and variations of these policies and measures within each energy sub-sector.

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In the **transport sector**, the key policies and measures that are commonly implemented to reduce emissions, and their likely impact on SLCPs and air pollutants include:

Increasing vehicle fuel efficiency through vehicle inspection and maintenance programmes, vehicle import age limits and renewal of the vehicle fleet.

- Increasing the fuel efficiency of vehicles can, but does not necessarily, also reduce air pollutants, because the emission control technology fitted to the vehicle determines the emission level of key air pollutants. More recently manufactured vehicles may meet more stringent vehicle emission standards, as well as being more fuel efficient. To assess the impact of policies to improve fuel efficiency on SLCPs and air pollutants in addition to GHGs, any such evaluation should consider how the policy will impact the percentage of the vehicle fleet meeting different vehicle emission standards.

Increasing the percentage of electric vehicles in the vehicle fleet.

- Electric vehicles have no exhaust emissions of air pollutant or SLCPs and are therefore an effective measure to simultaneously reduce both GHGs and air pollutants. There are particular local benefits to this: in many urban areas, exhaust emissions from road transport is one of the main contributors to poor air quality. Reducing this would radically improve air quality where public exposure would be expected to be greatest. The increase in demand for electricity required for vehicle charging may require increased energy generation at power stations which in turn can raise emissions of GHGs and air pollutants from that sector.

- It should be noted that the greater weight of electric vehicles means that air pollutant emissions from brake and tyre wear do increase somewhat. These can be significant air pollutant sources from the sector, especially where exhaust particulate matter emissions from internal combustion engines have been controlled through stringent vehicle emission standards. Therefore, evaluation of the air pollutant benefits from electric vehicles should consider implications for non-exhaust air pollutant emissions. Methodologies for estimating emissions of air pollutants from road dust, and brake and tire wear, are available from the EMEP/EEA Guidebook

Modal shift: Shifting passengers and freight between modes to reduce emissions.

- Improving public transport to encourage its use over private vehicles and/or shifting freight from road to rail are common policies and measures to reduce GHG emissions, due to the more efficient transport of people and goods. The impact on SLCP and air pollutant emissions could also be positive but depends on the balance of emission reductions from the transport mode being reduced and those that the passengers/freight are being transferred to. In evaluating the modal shift, SLCP and air pollutant emissions in alternative scenarios with and without the modal shift should be modelled to assess the overall effect.

SLCP and air pollutants could also be reduced by measures including the implementation of more stringent vehicle emission standards. For example, the Euro standards introduced in Europe from 1991 have since been applied in many countries worldwide, and have progressively tightened the emission limits for air pollutants. These standards do not limit GHG emissions from road transport, and therefore are a separate measure specifically designed for air pollutant reductions. Section 7 highlights that for a city in the Philippines, the development of an integrated historic emission inventory identified transport as the largest source, leading in turn to the identification of specific mitigation options in this sector.

In the **residential sector** key policies and measures designed to reduce SLCP and air pollutant emissions include switching from cooking or heating using solid biomass stoves to cleaner fuels. When the clean fuel substituted is Liquified Petroleum Gas (LPG), this can lead to substantial reductions in SLCPs and air pollutants. Since LPG is a fossil fuel however, this can lead to a trade-off in terms of GHG emissions. As cooking and heating fuels are commonly biomass, it is important to consider the GHG emissions from deforestation and land degradation reported in the FOLU sector of any policy and measure in conjunction with shifts in emissions of air pollutants, SLCPs, and GHGs emitted during combustion. Additionally, if the policy shifts towards electrification, then considerations of whether the additional electricity demands would increase GHG and air pollutant emissions from power stations should be made.

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on Pexels

Key policies and measures designed to reduce emissions in the **industrial sector** include energy efficiency and switching to renewable fuels within manufacturing. Improving fuel efficiency and switching to clean fuels (e.g. hydrogen, renewable electricity) provide the opportunity to simultaneously reduce air pollutants and SLCPs alongside GHGs. When biomass is used as a replacement fuel in the industry sector, there is potential for trade-offs between GHG mitigation and air pollutants. Burning biomass may increase air pollutants emissions compared to other fuels, unless emission control technologies (e.g. particulate filters) are deployed when the biomass is combusted. This is the case for Norway, for example, where action to discourage domestic wood combustion and promote the use of clean stoves was aimed at reducing emissions of black carbon and other harmful air pollutants, including other primary PM, polycyclic aromatic hydrocarbons, and methane (See **Section 7** for further details). This highlights the importance of considering GHGs, SLCPs, and air pollutants together. Action to discourage domestic wood combustion and promote clean stoves would have significant co-benefits to reduce both BC and methane. The reduced CO_2-emissions from biofuel will however not be included in the calculations according as the impact on emissions of CO_2 when considered with a 100-year GWP is zero.

As with the residential sector, evaluations should include the impact of deforestation reported in the FOLU sector to produce this biomass.

For **electricity generation**, the main mitigation measures include increasing the proportion of electricity generated from renewable sources, such as wind, solar, thermal, hydro and other low-GHG emission sources including nuclear. This can simultaneously reduce emissions of SLCPs and air pollutants as well as GHGs, because these renewable electricity sources not only do not emit CO_2, but do not emit SLCPs and air pollutants either. Other measures include reducing transmission and distribution losses or implementing energy efficiency policies to reduce demand for electricity. The reduced requirement to generate electricity, if combined with reduced generation from fossil-fuel powered power stations in turn reduces emissions of all pollutants. When biomass is used as a fuel for electricity generation, there are potential for trade-offs between GHG mitigation and air pollutants. Burning biomass may increase air pollutants emissions compared to other fuels, unless emission control technologies (e.g. particle filters) are deployed when biomass is combusted.

Policies and measures in the **oil and gas production sector** to reduce fugitive emissions include the reduction in planned flaring of associated and non-associated gas, and its utilisation for productive purposes. Also included is the implementation of advanced leak detection and repair in oil and gas infrastructure to reduce the rate of leakage. These policies and measures can all simultaneously reduce emissions of CH_4 and other volatile organic compounds, BC, and CO_2, because less gas containing these compounds is being lost from the oil and gas value chains. Therefore, controls of fugitive emissions will benefit both air pollutant and GHG emission reductions.

Industrial Processes and Product Use (IPPU)

In the IPPU sector, technical abatement measures for air pollutants and SLCPs are generally unlinked to measures implemented to reduce GHG emissions. Mitigation measures for air pollutant focussing on facility-level emission control technologies such as fabric filters and electrostatic precipitators can reduce particulate matter emissions from industrial processes.

Mitigation measures focusing on reducing demand for industrial products as a mechanism to reduce GHG emissions however, such as extending the life of buildings to reduce the consumption of cement, switching to alternative materials, increasing the recycling and reuse rates for materials such as metals, will simultaneously also reduce air pollution and SLCP emissions. For chemical products, reducing their demand, such as greater use of organic fertilisers compared to synthetic fertilisers, will simultaneously reduce air pollution and SLCP emissions. For fertiliser consumption, this can also impact GHG, SLCP and air pollutant emissions in the agriculture sector, as discussed on the following pages.

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Agriculture, Forestry and Other Land Use (AFOLU)

Key policies and measures to reduce GHG emissions in the AFOLU sector that have substantial synergies with reducing SLCPs and air pollutant emissions include:

Increasing the productivity per animal through improvements in livestock health, longevity, growth rate, breeding and feeding strategies tends to reduce both CH_4 emissions from enteric fermentation and manure and nitrogen excretion (related to N_2O, NH_3 and NO_x emissions) per unit of production.

The same synergy is also true for any policies which reduce production of livestock products through e.g. reduction in on-farm or post-farm gate food waste, or a shift in human diet away from animal products.

Anaerobic digestion of manure can provide reductions in both CH_4, NH_3 and NMVOC emissions (but this depends on the quality of the equipment as well as how digestate is stored and subsequently applied to the land). A benefit of anaerobic digestion is its effectiveness in processing manure into a form more useful to farmers (lower dry matter, high in nitrogen concentrations), which can displace synthetic fertilisers and their associated N_2O, NH_3 and NO_x emissions, as well as the GHG footprint associated with its production.

Acidification of manure (currently only common in Denmark) reduces NH_3, N_2O and CH_4 emissions.

Covering slurry stores with a solid cover reduces NH_3 emissions, but mixed results have been found for CH_4 and N_2O.

Adding nitrate to ruminant diets can reduce enteric methane emissions, but also replace some organic nitrogen in the diet so that nitrogen intake can be precisely controlled to prevent excessive nitrogen excretion.

Photo by Oleksander Pidvalnyi on Pexels

However, there are also some potential trade-offs which should be accounted for. Enteric methane emissions can be reduced through low-fibre diets for ruminants, or more generally a shift in livestock production from ruminants to pigs and poultry which mainly rely on concentrate feeds. The protein content of feed however, must also be considered to avoid excessive nitrogen intake (e.g. from high-protein cereals). Also, raising more pigs and poultry on concentrates in intensive facilities results in point-source pollution issues. At the opposite end of the spectrum, increased grazing time is an effective NH_3 mitigation measure as nitrogen in urine is quickly immobilised in the soil. However, grazing limits the ability to control diet protein and fibre content, so there may be trade-offs with enteric methane and N_2O emissions.

Measures to reduce volatilisation losses of NH_3 and NO_x from mineral and organic fertiliser application also help to reduce GHG emissions, through a reduction in indirect N_2O emissions from atmospheric deposition. Perhaps more importantly, if these and other measures that match nitrogen additions to crop requirements in space and time are applied, it will also reduce the total amount of nitrogen being applied to soils in fertilisers overall (due to lower losses), which reduced direct N_2O emissions from soils. Where this reduction occurs mainly in synthetic fertilisers, this has a win-win effect in also reducing the considerable GHG emissions arising from fertiliser manufacture.

Key measures include:

Using nutrient management plans to predict crop nitrogen requirements in time and space, coupled with soil and manure nutrient testing to ensure the right application rates are used.

Replacing use of chemical urea (which has high volatilisation rates of NH_3) with other fertilisers such as ammonium nitrate.

Using urease inhibitors with synthetic and organic fertilisers to reduce volatilisation.

Deep placement of mineral fertilisers.

Low-emission slurry spreading (injection, trailing hose or shoe).

Rapid incorporation of surface-spread solid manure.

Variable-rate application technology (a.k.a. precision fertiliser application).

However, other mitigation measures designed to reduce GHGs can result in trade-offs with emissions of other pollutants, including:

→ Nitrification inhibitors reduce emissions of N_2O and N, but can increase the rate of NH_3 volatilisation as nitrogen stays in ammoniacal form for longer.

→ The measures listed above which reduce volatilisation losses of nitrogen could, if application rates are not adjusted downwards to reflect the lower losses, actually increase direct N_2O emissions due to the larger quantity of nitrogen remaining in the soil, available for microbial metabolism. Therefore, to avoid this trade-off the careful planning and adjustment of fertiliser application rates following abatement measures is crucial.

→ Mechanical incorporation of manure implies higher fuel consumption and CO_2 emissions from machinery.


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Field burning is highly polluting and produces significant amounts of particulate matter, BC, and carcinogenic pollutants like benzo[a] pyrene. For agricultural residue burning, outright bans on field burning of agricultural residues and grasslands/savannahs are the main policy that has been implemented to control emissions from the practice. However, the alternative to burning is important in determining the overall impact on GHGs, SLCPs and air pollutants from avoiding burning of agricultural residues. Alternative uses of agricultural residues including economic utilisation for bedding, feed, building materials or fuel (bedding, fuel etc.). Other uses include re-incorporation of agricultural residues into the soil, for example through minimum or zero tillage practises.

If successful, by reducing the rate of occurrence of burning, emissions of all air pollutants, and SLCPs from combustion will be reduced. If residues are incorporated rather than burnt, there will be an increase in the quantity of nitrogen added to soils in crop residues. This could potentially result in increased N_2O emissions from soils, though this would be counteracted by the additional carbon added to the soil, leading to increased carbon sequestration and a reduction in the net CO_2 emissions from agricultural soils. The risk of increased N_2O emissions could be partly mitigated if fertilisation of the subsequent crop is reduced to account for the additional nitrogen input from crop residues.

Waste

Within the solid and liquid waste sectors, policies and measures put in place have often not been designed to mitigate emissions but were instead developed for broader health and environmental protections, such as improvements in sanitation (The World Bank, 2012). Responsibility for the waste sector is also often delegated from national governments to the subnational scale (e.g. municipal, state or other local authorities). This may mean that when considering those that can reduce GHGs, SLCPs and air pollutants, it may first be necessary to consider amendments to existing policies not designed with emission reductions in mind, and there may be different appropriateness, acceptability, and feasibility of policies and measures across a country.

Solid waste management policies and measures can have far reaching and cross-sectoral impacts in terms of influencing the profile of gases and pollutants released into the atmosphere. Recycling centres, whilst contributing no direct emissions from waste treatment, replace virgin materials with recycled materials in supply chains. Their impact therefore, may be cross-sectoral and more complex than simply reducing emissions from landfill models.

A reduction in methane emissions through reduced landfilling may lead to increases in other gases and pollutants depending on where the waste is diverted to. Modern energy recovery facilities can be extremely efficient but will contribute to emissions of CO_2 (including fossil CO_2 for, e.g. plastic waste) and air pollutants. It is important to note that waste to energy projects would reduce the use of other fuels for energy production, which could lead to an overall reduction in GHG and air pollutant emissions from the energy sector. Direct emission measurements may be available from these facilities to aid inventory compilers and policy evaluators, and should be prioritised, as Tier 1 emission factors may be uncertain and misrepresentative for most

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gases and pollutants. Diverting organic waste from landfill to biological treatment would reduce CH_4 emissions, as CH_4 emissions associated with biological treatment are significantly lower than those from landfill. Diverting waste from open burning to biological treatment could also reduce emissions of air pollutants..

Where solid waste is currently being dumped or open burnt at a local or regional scale, as is common practise in developing countries, expanded waste collection policies could in fact initially cause an increase in GHGs (as methane) if this increases waste that is handled at municipal landfills. Emissions of air pollutants would, however, be expected to be reduced.

Measures to increase the collection and treatment of wastewater at Waste Water Treatment Plants (WWTPs) will increase emissions from this category. Advancements in treatment technologies may further influence the profile of emissions released to air.

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Development of an integrated air pollution and climate change mitigation assessment for Togo

The approaches and considerations outlined above in the evaluation of policies and measures in an integrated assessment of air pollution and climate change have been put in place in a large number of global, regional and national assessments (Amann et al., 2017; Kiesewetter et al., 2015; Kuylenstierna et al., 2020; Nakarmi et al., 2020; UNEP/WMO, 2011; UNEP, 2019, 2018). A recent example, which provides a useful case study, is the integrated air pollution and climate change mitigation assessment undertaken to inform the updating of Togo's NDC in 2021 (Agbossou et al., 2022; Togolese Republic, 2021). The emissions mitigation assessment undertaken during the process of updating Togo's NDC aimed to identify how Togo could reduce air pollutant emissions alongside GHGs, to achieve local benefits from implementing Togo's NDC.

To do so, a scenario analysis, as outlined above, was undertaken to quantify GHG, SLCP and air pollutant emissions using consistent methods for different time periods. First, an historic emission inventory (2010-2019) was developed for GHGs, SLCPs and air pollutants. A common set of activity data was used in the development of the inventory (as outlined in **Section 3**). The sources of activity data for the historical inventory were mostly taken from national data sources. For example, the national energy balance for Togo provided fuel consumption data for the majority of the energy sectors, while the Road and Rail Transport Directorate of Togo collected data on the vehicle fleet for the transport sector emissions analysis. Not all sectors had locally available data from which historical GHG, SLCP and air pollutant emission inventories could be derived, and therefore international default activity data was used. In this case, crop production data to quantify agricultural methane emissions from rice production was taken from the Food and Agriculture Organization's FAOStat database. Due to the lack of country-specific emission factors, default emission factors for GHGs (from IPPC (2006), and air pollutants (EMEP/EEA (2019)) were used.

The extension of an historic inventory to evaluate policies and measures requires the development of future scenarios. For the baseline scenario in Togo, the approach outlined above was used in which activity in key sectors were linked to proxy variables, as summarised in Table 5 on the next page. The baseline scenario projections included the expansion of electricity based on current plans by the Ministry of Energy. While activity in the residential sector was linked to population growth, and for other sectors was linked to economic growth (Table 5).

Table 5: Overview of assumptions and proxy variables used to create baseline in integrated air pollution and climate change mitigation assessment in Togo.

Source Sector	Variable used for base-line projections	Value	Source of data
1A1a Public electricity and heat production	New installed capacity for electricity generation	Centrale thermique CEET: 50 MW in2025	Revised NDC (Togolese Republic, 2021a)
1A2 Manufacturing industries and construction	Fuel consumption in industrial sector	Centrale Kekeli 65 MW in 202. Growth in energy consumption in industrial sub sectors: Non-metalic minerals: 2% per year Food, Beverage and Tobacco: 1% per year Construction: 1% per year Other industries: 1% per year	Revised NDC (Togolese Republic, 2021a) Revised NDC (Togolese Republic, 2021a)
1A3b Road transportation	Passenger- km (passenger transport demand)	12% per year increase	Revised NDC (Togolese Republic, 2021a)
	Tonnes-km (freight transport demand)	6% per year increase	
1A4a Commercial/ institutional	Fuel consumption in services sector	All fuels: 1% per year Electricity: 2% per year	Revised NDC (Togolese Republic, 2021a)
1A4b Residential	Number of households	Population growth: Population 2010: 6.191 million 2015: 6.835 million 2018: 7.352 million 2020: 7.706 million 2025: 8.624 million 2030: 9.575 million	
	% Households urban	42% urban in 2018; 50.5% urban in 2030	
	Electricity access	Urban: 84% access in 2018, 100% in 2030 Rural: 9% access in 2018, 100% in 2030	
2A Mineral industry	Cement production	1% growth per year	Revised NDC (Togolese Republic, 2021 a)
2F Product uses as substitutes of ozone depleting substances	Refrigeration and air conditioning	Consumption: 2013-2020 average consumption	Revised NDC (Togolese Republic, 2021a)
3A Livestock	Number of animals	2.3% per year growth	Revised NDC (Togolese Republic, 2021a)
3B Land	Land (forest, plantation, crop, grassland, wooded grassland, wetland, settlement) remaining land type	Deforestation/afforestation rates, annual biomass growth rates, losses due to disturbances remain at 2015-2018 average values.	Revised NDC (Togolese Republic, 2021a)
	Land converted to other land types	Biomass losses due to fuel-wood grow at a rate of biomass consumption in residential and commercial energy sectors.	
3C Aggregate sources and non-CO_2 emission sources on land	Rice and other crop production	2.84% per year growth in rice production	Revised NDC (Togolese Republic, 2021a)
	Amount of fertilisers applied	2.3% per year increase in fertiliser consumption	
	Area burnt in grasslands, forest-lands, croplands		
3D Other			
4A Solid waste disposal on land	Municipal solid waste generated	Population growth rate	Revised NDC (Togolese Republic, 2021a)
4D Liquid waste	Wastewater generated	Population growth rate	Revised NDC (Togolese Republic, 2021a)

Ten mitigation measures were assessed to quantify the extent to which they reduced GHGs, SLCPs and air pollutants. These are summarised in Table 6 below and provide a useful example of the necessary information to represent a mitigation measure quantitatively, i.e., a specific implementation target and timeline. All ten mitigation measures listed outline a specific implementation target, e.g. 35% of household cooking using LPG, and a timeline for its achievement (e.g. 2030). The mitigation measures selected for inclusion within the evaluation of policies and measures in Togo also mirror many of the measures included in Table 6 that have been identified broadly as leading to simultaneous reductions in GHGs, SLCPs and air pollutants, indicating that the measures underpinning Togo's NDC are well selected to mitigate both climate change and local air pollution.

Table 6: Polices and measures evaluated in integrated air pollution and climate change mitigation assessment in Togo.

Sector	Mitigation measure	Plan/Strategy
Electricity Generation	Expansion of renewable electricity generation: - 50 MW solar in 2021, 99 MW in 2023 - 86.2 MW additional hydro capacity in 2023	Revised NDC (Togolese Republic, 2021a)
Transport	Increase percent of electric vehicles in fleet: - 1% of passenger cars electric by 2030	National Renewable Energy Action Plan (PANER) (Ministry of Mines and Energy of Togo, 2015) Revised NDC (Togolese Republic, 2021a)
	Improve efficiency of transport: 20% improvement in fuel efficiency of vehicle fleet in Togo by 2030	National Renewable Energy Action Plan (PANER) (Ministry of Mines and Energy of Togo, 2015) Revised NDC (Togolese Republic, 2021a)
Residential	Increase percentage of households cooking using clean fuels or more efficient biomass stoves	Revised NDC (Togolese Republic, 2021a)
	By 2030: Urban Households: • 35% of urban households cooking using LPG • 12% of urban households cooking using biogas • 15% of urban households cooking using biomass briquettes • 72% of urban households cooking using wood switch to more efficient biomass stoves (20% more efficient than base case energy consumption shown in Table 5) • 90% of urban households cooking using charcoal switch to more efficient biomass stoves (48% more efficient than base case energy consumption shown in Table 5) Rural Households: • 8% of rural households cooking using LPG • 15% of rural households cooking using biogas • 10% of rural households cooking using biomass briquettes • 72% of rural households cooking using wood switch to more efficient biomass stoves (20% more efficient than base energy consumption shown in Table 5) • 90% of rural households cooking using charcoal switch to more efficient biomass stoves (48% more efficient than base case energy consumption shown in Table 5)	
Charcoal Production	Increase charcoal produced using more efficient kilns (26% efficiency vs 11% efficiency in baseline) = 100% conversion by 2030	Revised NDC (Togolese Republic, 2021a)
Agriculture	Reduced in emission intensity of livestock and crop production: • 1% per year reduction in methane emissions from enteric fermentation and manure management • 1% per year reduction in fertiliser consumption • 1% per year reduction in land continuously flooded for rice production • 2% per year reduction in crop residue openly burned in fields	Revised NDC (Togolese Republic, 2021a)
Forestry	Implementation of residential cooking measures above reducing fuel wood demand	Revised NDC (Togolese Republic, 2021a)
	5% reduction in forest area under forest fire by 2020 compared to 2018 levels.	
	5% increase in land converted to forest land in 2030 compared to 2018 levels (i.e. 86,000 ha y $^{-1}$ converted to forest land by 2030)	
Waste **Transport**	4500 t methane recovered from landfill sites through landfill gas capture by 2030 100% of vehicles meet Euro IV vehicle emissions standards by 2030	Revised NDC (Togolese Republic, 2021a), National Action Plan on Air Pollutants and SLCPs (Togo Ministry of Environment, 2020)
Waste	Reduce open burning of waste by 30% by 2030	National Action Plan on Air Pollutants and SLCPs (Togo Ministry of Environment, 2020)

Once modelled in the evaluation of policies and measures, the assessment in Togo highlights some key outputs that can be achieved when integrating assessment of GHGs, SLCPs and air pollutants. First, the common and overlapping sources of different pollutants can be identified (Figure 10). In 2018 in Togo, the residential sector was the largest source of a significant number of different pollutants, (BC, PM$_{2.5}$, VOCs). While Forestry was the largest net source of CO$_2$, transport was the second largest source, as well as being a major source of volatile organic compounds and NO$_x$ air pollutant emissions. Secondly, the assessment also demonstrates that a package of mitigation measures can achieve large reductions across GHGs, SLCPs and air pollutants (Figure 11). The full implementation of all mitigation measures can reduce GHG emissions by just over 20%, and primary PM$_{2.5}$ emissions by over 50%. The effectiveness of the measures within this package can be evaluated for different pollutants. In Togo, air pollutant emissions are reduced mostly through actions to switch to more efficient stoves or cleaner fuels for cooking. Measures to reduce deforestation are the most effective measures to reduce CO$_2$, which include reducing wood use for cooking, emphasising the strong link between climate change and air pollution actions in Togo. This demonstrates how an integrated inventory and policy evaluation process has enabled the development of a set of policies identified to achieve Togo's NDC that will bring benefits for greenhouse gases and air pollutants, and can be used to more quantitatively assess the wider impacts, such as the impact on public health, as discussed in the next section.

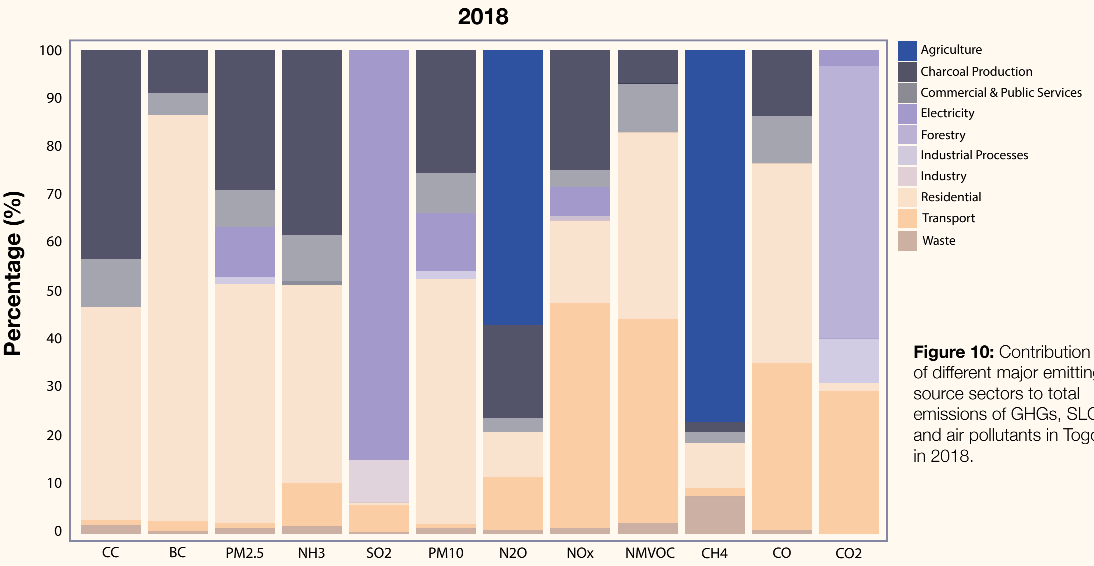

Figure 10: Contribution of different major emitting source sectors to total emissions of GHGs, SLCPs, and air pollutants in Togo in 2018.

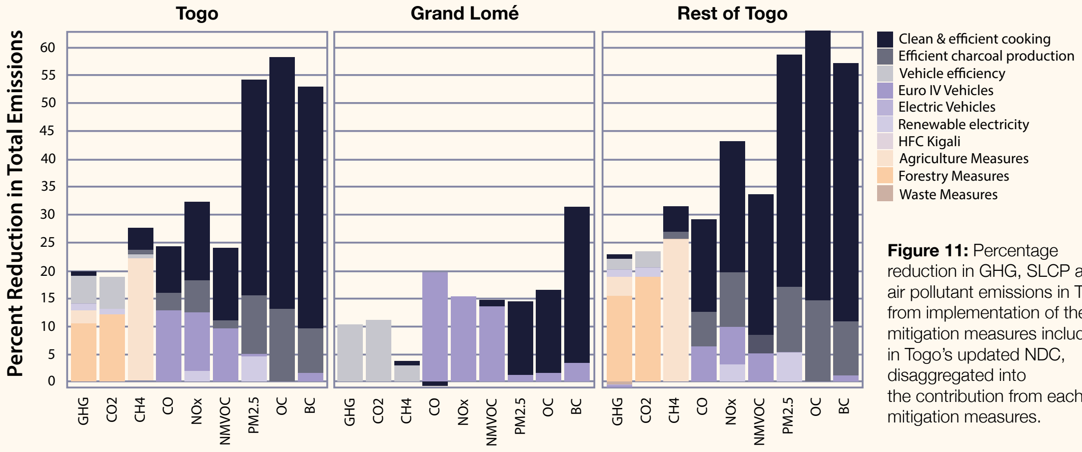

Figure 11: Percentage reduction in GHG, SLCP and air pollutant emissions in Togo from implementation of the 10 mitigation measures included in Togo's updated NDC, disaggregated into the contribution from each mitigation measures.

5

Evaluating the Health Impacts of Emission Reductions

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Key messages

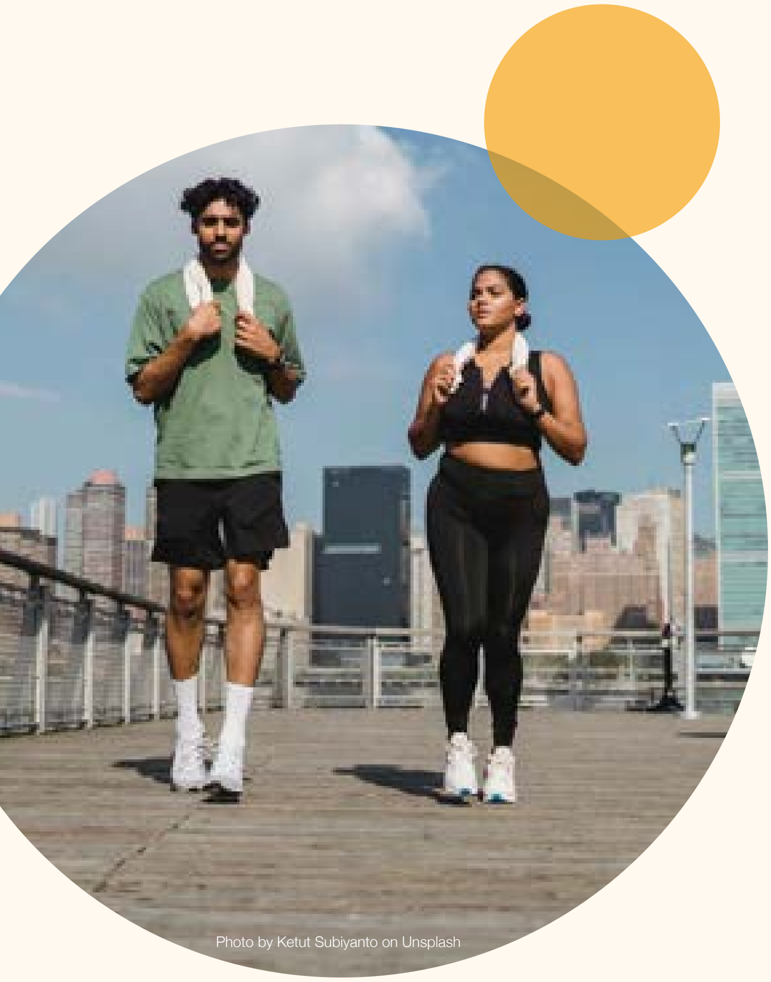
1 **Air pollution has a substantial impact on human health, and policies and measures designed to reduce emissions can alleviate this impact. Air pollution health impact assessments quantify the magnitude of health impacts that have or could be avoided from implementation of these policies and measures.**

2 **Air pollution impacts health through exposure to a given concentration of air pollutants (e.g. $PM_{2.5}$) in the atmosphere. The concentration of air pollutant depends on the strength of air pollutant emission sources, and the atmospheric transport and chemical reaction of pollutants in the atmosphere. Quantifying air pollution health impacts from specific sources or benefits from implementation of policies and measures requires that this air pollution chain from emission to atmospheric transport to concentrations and exposure and finally health burden is modelled.**

3 **An evaluation of the air pollutant emission reductions is a prerequisite to undertake a health impact assessment. There are multiple approaches and tools that can be used to assess air pollutant health impact assessments which range from simplified tools that can rapidly assess air pollution health benefits, to comprehensive atmospheric modelling approaches.**

Overview of assessing health impacts of emission reduction policies

The aim of this section is to provide an overview of the methods and approaches that can be used to quantify the specific health impacts of changes in air pollutant emissions in response to the implementation of particular policies and measures. The methods in this section are consistent and can be used in combination with those outlined in **Sections 3 and 4**. This Section outlines how the quantification of emissions can be extended to estimate how these emissions link to atmospheric concentrations and human exposure to the air pollutants that are most damaging to human health (fine particulate matter, $PM_{2.5}$ and ozone, O_3). It also provides guidance on how exposure to $PM_{2.5}$ and O_3 can then be combined with exposure-response functions to quantify the change in incidence of specific diseases that are associated with air pollution exposure.



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Framework for quantification of health benefits from climate change mitigation

Air pollution exposure is only one of the health risks that is impacted by climate change mitigation actions. The health impacts from climate change mitigation can be grouped into two broad categories. The first concerns those arising from the averted climate change resulting from avoided GHG emissions, such as reduced heat-related mortality and morbidity. The other category includes health impacts from changes in exposure to different health risks as a result of the implementation of climate change mitigation action. This category includes changes in air pollution exposure due to the implementation of mitigation measures. Other examples include changes in diets, active travel including walking and cycling, and water and sanitation. More broadly, impacts on human health are one of a subset of sustainable development benefits that could be impacted by the implementation of climate change mitigation measures. Different methods and approaches for the inclusion of other health risks, and other development benefits in climate change MRV frameworks are provided in the ICAT guide on sustainable development impacts (ICAT 2018).

Estimating the health benefits from changes in exposure to health risks from the implementation of climate change mitigation can help drive more ambitious goals and health protective actions. As described in a Commentary published by a large group of climate and health researchers in the journal *Environmental Health Perspectives*, "Guidelines for modelling and reporting health effects of climate change mitigation actions" (Hess et al., 2020). There are many pathways through which climate change mitigation actions improve public health, many of which are relatively immediate, and benefits accrue locally where the actions are being taken. However, some climate change mitigation actions are more health beneficial than others, and some may not lead to health benefits at all. For example, carbon capture and sequestration is unlikely to lead to health benefits if fuel combustion continues at the same level, because fuel combustion and, therefore, air pollution would continue unabated. On the other end of the spectrum, displacing personal vehicle use with active mobility (e.g., walking and cycling) would be very health beneficial, because in addition to the greenhouse gas emission reductions, this action would reduce air pollution and improve physical fitness and mental health. Figure 12 below illustrates some examples of links between broad GHG mitigation opportunities and health outcomes. Most of these health benefits occur locally to the population where the greenhouse gases are being reduced, and relatively immediately (within months to years) compared with the long-term influence on the climate system.

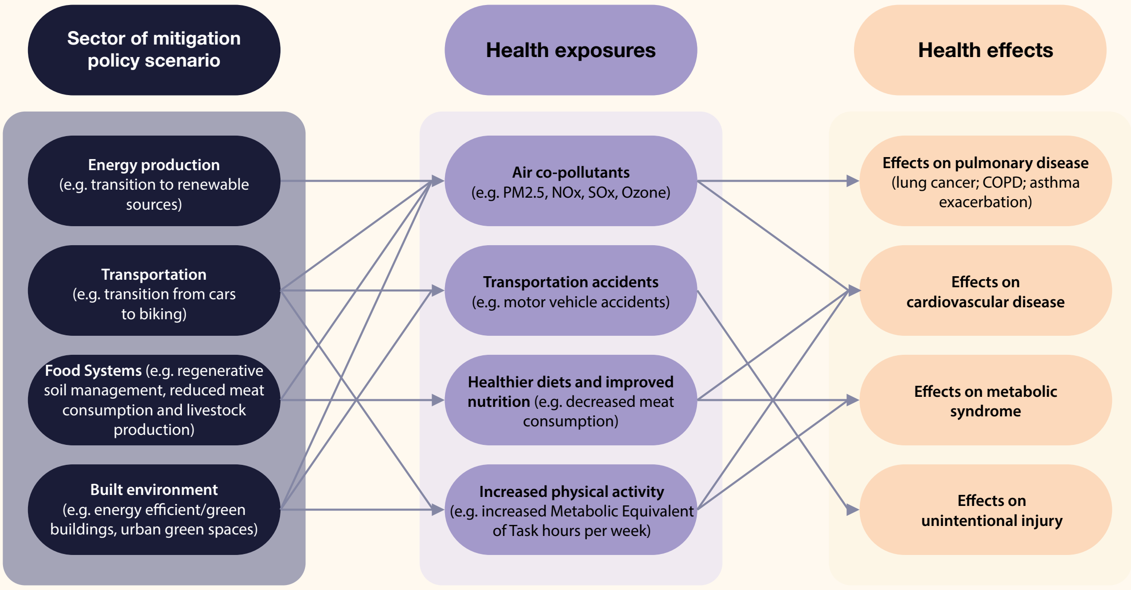

Figure 12: Conceptual framework illustrating examples of pathways through which greenhouse gas mitigation improves public health, reproduced from Hess et al. (2020).

As outlined by Hess et al. (2020), the general framework for estimating health benefits of GHG mitigation includes:

1

Scoping/baseline:

- Determine population of interest (i.e., exposed to health risk) and time scale of analysis (i.e., historic period covered, future years for projections).
- Obtain or estimate historic values of key inputs to health impact assessment, including demographics, health status, and exposures or levels of health risks.
- Obtain or estimate future trends in demographics, health status, and exposures or levels of health risks for the baseline scenario to estimate health impacts without implementation of identified mitigation strategies.
- Identify mitigation strategies and quantify associations with drivers of health impacts (i.e., relationship between exposure to health risk and implementation of mitigation strategy).

2

Impact assessment

- Estimate changes in health drivers and health risk exposures associated with mitigation strategies relative to baseline and/or historic health impacts.
- Estimate changes in health status, e.g., incidence of diseases attributable to health risk, resulting from changes in exposure to health risk.

3

Valuation

- Estimate economic value of changes in health status.
- As appropriate, estimate costs of mitigation strategies for comparison purposes.

4

Sensitivity/uncertainty analysis

- Conduct appropriate sensitivity and uncertainty analysis, refining valuation and impact assessment parameters through further, targeted research.

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Additional detailed recommendations for modelling approaches given by Hess et al. (2020) include guidelines for stakeholder engagement, modelling approaches (mitigation policies, geographic area and scale, population and demographic considerations, counterfactual scenarios, time frames and horizons, exposure-response functions, health metrics, baseline health estimates), and parameterization and reporting (health outcome reporting, accounting for variable policy uptake, discounting, data and code transparency).

Of the pathways through which GHG mitigation actions improve public health, air quality is potentially the most impactful, yielding the largest number of avoided cases of mortality and morbidity. Methods to assess health benefits from reduced air pollution, both in terms of cases of disease and mortality avoided and the economic value of those health improvements are also widely available and have been applied over decades to support air quality regulation and in other contexts around the world. Decision-support tools are also now available for automating the process of estimating health impacts of air pollution, for a variety of geographies and policy contexts. Commonly applied decision-support tools include:

- Air Q+
- LEAP which is highlighted in the Case Study for Colombia (**Section 7**)
- BenMAP
- GAINS
- AIRPOLIM-ES for air pollution impacts from electricity supply
- TRACE for assessing co-benefits from decarbonising transport

Thus, estimating the avoided mortality and morbidity from improved air quality can be a relatively straightforward addition to climate change monitoring and transparency frameworks. Because the health benefits can readily be expressed in economic terms (i.e. dollar values) as well as the avoided health burden (i.e. cases of disease and mortality). Health benefits of climate change mitigation actions can be included in cost-benefit and cost-effectiveness analyses.

Applying health impact assessment to assess air pollution health benefits

The generic method outlined above for quantifying the health impacts of climate change mitigation can be applied to quantify the health impacts from changes in air pollutant emissions resulting from climate action. This section describes key considerations for assessing the health impacts of air pollution changes related to climate change policies. Figure 13 on the following page illustrates the process involved in conducting air pollution health impact assessment, including data inputs and outputs. This involves:

1. **Quantifying the air pollutant and emissions that are emitted alongside GHGs from all major source sectors historically, and in baseline and mitigation scenarios in the future.** This step is covered in **Section 3** and **Section 4.**

2. **Spatially distributing air pollutant emissions across the geographic area of interest.** Air pollution exposure, and health burdens, depend on the relationship between where air pollutants are emitted (i.e., the location of the source), and the population that are exposed to them (i.e. the receptor). Therefore, in contrast to GHGs, to understand the health burden from air pollution, national, regional or city total air pollutant emissions need to be spatially distributed.

3. **Linking spatial air pollutant emissions to changes in a population's exposure to air pollutant concentrations.** Following emission, air pollutants are transported by weather patterns from their source to other locations, and chemically react in the atmosphere to form other pollutants. The transport and chemical transformation of air pollutants in the atmosphere determine people's exposure to health-damaging air pollutants like $PM_{2.5}$ or ozone and how changes in air pollutant emissions in one location impact this exposure, which can often be in non-linear ways. A range of approaches are available to quantify this relationship, ranging from relatively simple factors that convert changes in emissions to changes in concentrations, to complex atmospheric chemistry transport models. The output from this step is the quantification of the change in concentrations of air pollutants (e.g., $PM_{2.5}$ or ozone) from applying different mitigation strategies, compared to either a baseline projection, or historical years.

4. **Applying health impact assessment to convert changes in air pollutant exposure to changes in health burden.** In this step, the changes in $PM_{2.5}$, or ozone (or other air pollutant) exposure is combined with data on the population exposed, baseline mortality rates for diseases linked to air pollution, and concentration-response functions quantifying the increased risk of mortality for a given change in exposure to an air pollutant, to quantify the change in mortality or morbidity due to a change in air pollutant exposure. This step provides the impact on health from implementation of the climate change mitigation strategies, and can be calculated separately for different age groups, male and female, disease groups or other population disaggregation.

These steps are performed for each set of pollutant concentrations (e.g., for each emissions scenario), and can be applied to different types of air pollutant exposure. Typically, air pollutant exposure is categorised into exposure to ambient (or outdoor) air pollution and household (or indoor) air pollution. Ambient exposure to $PM_{2.5}$ or O_3 estimates the overall exposure to air pollution from the totality of sources that contribute to outdoor air pollution concentrations in a particular location. Exposure to household $PM_{2.5}$ concentrations estimates the exposure of populations where the fuel used for cooking or heating (typically estimated for biomass, coal and/or kerosene) dominates overall exposure to air pollution. In some countries, there are populations that are exposed to high levels of ambient and household air pollution, and the combined impact of exposure to both sources should be taken into account.

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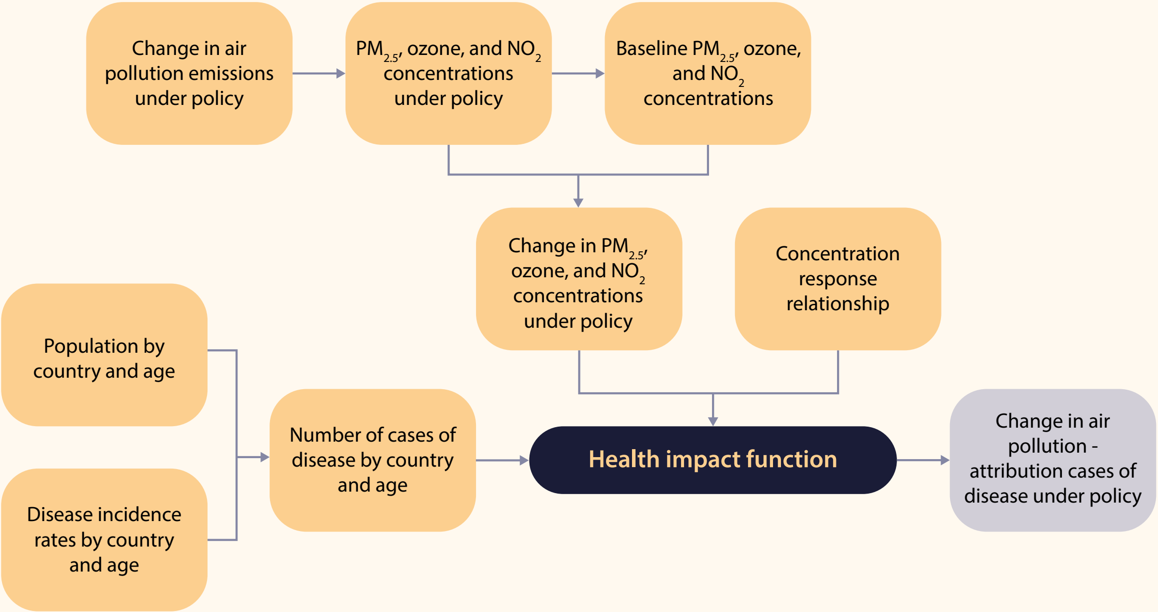

Figure 13: Diagram of process for estimating changes in air pollution-attributable cases of disease under emissions policies.

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Spatial distribution of air pollution and SLCP emission changes

GHG mitigation policies occur in a variety of air pollution-emitting sectors, including energy generation, industrial, transportation, agriculture, household energy and others. As these sectors have different spatial distributions, their air pollution emissions also differ spatially. While climate impacts of GHG emission changes are relatively insensitive to emission location, air pollution effects are highly dependent on where emissions occur since chemical fate and transport processes are location specific. In addition, health impacts associated with air pollution are driven by both pollution levels and the size of the population nearby.

To accurately estimate health and crop impacts, methods are necessary to spatially distribute national-scale air pollution and SLCP emissions and their changes under policies. Several methods are commonly used and typically involve the identification of a proxy variable whose spatial distribution is likely to be highly correlated with the activity resulting in emissions from a particular source and/or the spatial distribution of emissions from that source. For example, for point sources (emission sources that are emitted from a facility with a fixed location such as power plants, major industrial facilities, ports and airports), emissions from electricity generation and industry can be spatially allocated to these specific locations, if the location of these facilities is known in the country of interest. International databases of power plants and industrial facilities (for particular industries) are available in the absence of country-specific information.

For line or non-point sources, e.g., roads, road transport emissions can be allocated to grid that characterise the distribution of roads, taking into account primary, secondary and tertiary roads, and, ideally, traffic density. Different assumptions about the distribution of emissions from heavy duty freight vehicles compared to passenger cars or public transport may also be made if information on traffic density is available for different vehicle types. International databases are available on road networks globally, which could be used as proxy variables, but they do not provide information on the density of vehicles on these roads.

Finally, diffuse sources include emission sources which are often distributed based on the population density. Such sources could include emissions from households, ideally accounting for differences in predominant fuels in urban and rural areas, which often differ, and open burning of waste. Global population density datasets are readily available, for example the Gridded Population of the World (GPW). Other diffuse sources include those associated with agricultural activities such as livestock (methane, nitrous oxide, nitrogen oxide and ammonia emissions from manure management) and crop production (fertiliser application, open burning of agricultural residues), which are often distributed based on spatial distribution of livestock and crop production as well as differences in management systems (e.g., intensive vs subsistence). Global livestock and crop production spatial datasets are also available in the absence of country-specific data. Where “bottom-up” country-specific spatial allocations are not available, “top-down” emissions estimates from global and regional emissions inventories are available (e.g. the Community Emissions Data System, CEDS, (McDuffie et al., 2020)).

Estimating ambient pollution changes from emission changes

Once emissions are spatially distributed, the next step is to estimate the change in pollution concentrations resulting from changes in emissions. For ambient air pollution, this step is one of the more complex steps in estimating health benefits from improved air quality under policies, because

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pollution concentrations are influenced by more than emission levels. Meteorology, chemistry, and other processes are also important influences on $PM_{2.5}$, ozone, and other pollutant concentrations, and their changes in response to emission reductions.

The most rigorous, but also most resource intensive, approach to estimating pollution concentration changes resulting from emission changes is using chemical transport modelling. Chemical transport models are computationally-intensive computer models that include mathematical representations of chemistry and meteorological effects on pollution levels and simulate pollution levels in each location and altitude resulting from a change in the atmospheric system, such as emissions. Some examples of chemical transport models include GEOS-Chem and CMAQ. While these models provide rigorous estimates of pollution changes under policies, they are often prohibitively expensive and may require expertise and computing resources that are not available.

Screening-level approaches to converting emission changes to concentration changes are now available in some cases. Screening-level, or “reduced form” approaches, enable rapid calculation of concentration responses to emissions changes with much less computational cost compared to transport models. Several of the reduced form models used in various policy support tools rely on “emission-to-concentration sensitivities” which relate a unit change in emissions of direct and precursor air pollution emissions anywhere in the world to $PM_{2.5}$ and ozone concentrations at a particular receptor (e.g., country or regional average concentrations). These models make some simplifying assumptions such as linearity in the chemical response to emission changes, which works well for incremental emission changes (e.g., +/- 20%) but is less valid for larger emission changes (e.g., halving or zeroing out all anthropogenic emissions). Another general assumption is that the meteorological conditions used to generate the emissions-to-concentration sensitivities are static, even though these models are often used to assess future policy scenarios decades in the future when climate change might affect temperature, precipitation, and other meteorological conditions. **Section 7** provides an example of how a reduced form model (LEAP-IBC) was used to estimate the air pollution health benefits from implementing Colombia’s NDC.

For household air pollution, the key determinant of exposure to $PM_{2.5}$ is the fuel and the technology used for cooking/heating in a particular household. Hence to estimate changes in exposure to household air pollution at a population scale, the number of households cooking/heating using different fuels and technologies is first determined. An exposure is then assigned to different household members (typically primary cook, other adult and children) living in households using different fuels and technologies for cooking/heating. While country-specific information on the exposure of individuals in households cooking using different fuels may not be available, estimates from previous studies undertaken in similar settings could be used as an estimate of the magnitude of $PM_{2.5}$ exposure. For example, Schupler et al. (2018) undertook a review of all studies estimating exposure to people cooking using different fuels and developed regional averages for household $PM_{2.5}$ exposure estimates.

Estimating health impacts from air pollution changes

The process for quantitatively estimating mortality and morbidity impacts from air pollution exposure is called Health Impact Assessment (HIA). A common HIA method used both in policy contexts and in the academic literature is called the "population attributable fraction (PAF)" approach. The PAF approach to HIA is used by the US Environmental Protection Agency (US EPA) in regulatory support documents and by the WHO and Institute for Health Metrics and Evaluation (IHME) to estimate the global burden of disease from air pollution.

The first step is to combine epidemiologically derived concentration-response functions with concentration estimates to generate the attributable fraction, or the fraction of some health endpoint that is attributable to the pollutant. The second step is to calculate the number of cases of a health outcome (e.g. mortality) that are attributable to the pollutant by multiplying the attributable fraction by the baseline number of cases of the health outcome within the population of interest. The calculation is shown by Equation 2.

The calculation is shown by Equation 2.

$$M = Pop \text{ x } y \text{ } (RR\text{-}1/RR) \text{ } (2)$$

Where:

- ***M*** is the disease burden (e.g., pollutant-attributable deaths, cases of disease, or years of life lost) in geographic unit i for age group a and health outcome h,
-

  Pop is the population in the geographic unit i for age group a, Y is the baseline incidence rate (e.g., deaths, cases of disease, or years of life lost per 100,000 people) in country c for age group a and health endpoint h, and

- ***RR*** is the epidemiologically derived relative risk estimate for the pollutant concentration in geographic unit i for age group a and health endpoint h. The quantity in brackets is the Population Attributable Fraction (PAF) – the fraction of disease in a population that is attributable to the air pollutant.

This process can be performed for both historical and future years, as long as air pollution concentration estimates are available. It can also be performed for multiple emission scenarios. For example, health impacts could be calculated for a "business as usual" scenario and a mitigation or policy scenario, with the difference in health impacts calculated for each scenario representing the health benefits of the policy.

Consideration of health benefits from NDC action implementation in Ghana

Ghana's motivation to monitor SLCPs and air pollutants within climate change monitoring systems results from the substantial integration of SLCPs and air pollutants in climate change mitigation planning. Air pollution levels in Ghana exceed WHO standards, resulting in thousands of premature deaths per year. Between 2015 and 2019, Ghana went through a national SLCP planning process. Within this process, stakeholders were engaged to raise awareness of SLCPs and integrated air pollution and climate change mitigation strategies, technical analysis was undertaken to assess air pollutant, SLCP and GHG emission reduction potentials from priority mitigation measures, and plans were developed for the implementation of these measures. This SLCP planning process provided the first information on the magnitude of SLCP and air pollutant emissions, alongside GHGs, through the development of an integrated air pollution and climate change mitigation assessment.

Using the LEAP tool, historical emissions of SLCPs, air pollutants and GHGs were estimated, and projected into the future to assess the reduction in all emissions for different mitigation strategies representing the implementation of different policies and mitigation measures compared to a baseline scenario up to 2040. This analysis included quantifying the benefits on public health and found that a co-benefit of implementing the actions outlined in its updated NDC submitted in 2021, was the avoidance of over 2,900 premature deaths per year by 2030 through associated improvements in air quality. Ghana is one of only a few countries in the world to state quantitatively the health benefits achievable from the implementation of its NDC.

Typically, HIAs include pollutant-health outcome pairs that systematic reviews of the health literature find to be causally and likely causally associated, using for example reviews by the WHO or US EPA, 2009; WHO Regional Office for Europe, 2013). The Global Burden of Disease (GBD) 2019 study, the latest at the time of writing this guide (June 2022), estimates stroke, ischemic heart disease, lung cancer, lower respiratory infection, chronic obstructive pulmonary disease, diabetes mellitus type 2, low birth weight, and short gestational age associated with long-term $PM_{2.5}$ exposure; and COPD associated with long-term ozone exposure (GBD 2019 Risk Factors Collaborators 2020). The GBD 2020 Study is expected to also include paediatric asthma incidence associated with long-term nitrogen dioxide (NO_2) exposure. It is not necessary for each country to conduct a de novo systematic review of the evidence linking air pollution and health outcomes to determine which pollutants and health outcomes to include. Rather, countries can rely on the systematic reviews conducted by IHME, WHO, US EPA, or other high-quality sources.

The data inputs needed to conduct air pollution health impact assessment include concentration-response functions, population estimates, and baseline disease rates. For country-specific assessments, data can come from national or local sources, or from international datasets. National and local sources typically provide more accurate information for the population of interest, but may not exist, be difficult to obtain, or represent a limited sample size. International datasets may be less accurate for a local population of interest but may have the advantage of drawing from a much broader and more generalizable population. A practical approach would be to use national or local data available, and international datasets for data inputs for which national or local data are not available. For example, a country-scale health impact assessment could use national data for population and disease rates and, if no high-quality, long-term epidemiological study has been conducted in the country, concentration-response curves derived from international studies could be used.

Air pollution health impact assessments can also be performed for future years to explore the impact of emission changes expected under “business as usual” scenarios versus policy alternatives. Such assessments should consider changes in population and disease rates over time. Future population and mortality rate estimates can be obtained from the UN World Population Prospects up to 2100 under different projection variants (UN DESA, 2019). Demographic estimates become more uncertain over time, and policy analyses commonly assess impacts in the 2030-2050 time frame, though estimates farther into the future may be relevant in some decision contexts.

Concentration response functions are derived from risk ratios found empirically by epidemiological studies of large population cohorts. Risk ratios describe a difference in risk of disease or death for a group exposed to higher levels of air pollution compared with a group exposed to lower levels. A risk ratio greater than 1 indicates an increased risk for the exposed group, while a risk ratio lower than 1 indicates a protective effect of the exposure. Since large, long-term air pollution epidemiology studies are limited in countries outside of North America and Europe, many country-scale health impact assessments use concentration-response functions derived from meta-analyses of epidemiological studies conducted all around the world (See for example **Section 7** and the case study for assessing the health benefits of implementing Colombia’s NDC, which used an international concentration-response function). A key advantage of using these curves is that they integrate data from many air pollution epidemiology studies with large populations of varied exposure levels and $PM_{2.5}$ compositions, lifestyles, health care access, along with other characteristics that might affect air pollution health risks. Thus, they represent a generalizable concentration-response function that can be applied in any population, across the full range of concentrations. However, if high quality national cohort epidemiology studies exist, they may be more representative of the local population.

Two leading examples of these “international” concentration-response curves for $PM_{2.5}$ mortality are those developed for the Global Burden of Disease Study (GBD Study)(Murray et al., 2020) and the Global Exposure Mortality Model (GEMM) (Burnett et al., 2018). These curves and their evolution are described in detail by Burnett and Cohen (2020). Relative risks for PM2.5 and each age group and health outcome from the GBD 2019 study are provided by the authors as a lookup table that lists the age- and cause-specific RR (mean, lower confidence interval, and upper confidence interval values) for each $PM_{2.5}$ concentration step between 0 and 2,500 µg/m3 (step changes are in increments of 0.01 from 0-1 µg/m3, 0.1 from 1-10 µg/m3, 1 from 10-100 µg/m3, 10 from 100-1000 µg/m3, or 100 µg/m3 from 1,000-2,500 µg/m3). The mean RR for each $PM_{2.5}$ step can be used to estimate $PM_{2.5}$ mortality burdens. GEMM model parameters are provided by Burnett et al. (2018).

Population estimates can be drawn from national or local data or from gridded estimates. For health impact assessments that are not spatially explicit (e.g., one estimate of $PM_{2.5}$-attributable mortality for each country, year, and emissions scenario), national total population can be used. If the location of the air pollution-related health impacts is an objective of the analysis, population estimates can come from local data usually provided for small administrative units (e.g., county, province or finer) or from a globally gridded dataset. Multiple globally gridded population datasets can be used, including Worldpop (Tatem 2017) and Gridded Population of the World (CIESIN, 2016). These differ in terms of spatial distribution and assumptions about urbanicity and can be compared at https://sedac.ciesin.columbia.edu/mapping/popgrid/.

Two main data sources for baseline disease rates include national or local administrative data and global datasets of country-scale estimates. Administrative data can often be obtained directly from Ministries of Health or similar organization that maintain health records. However, in some cases administrative data may not be collected or available at the spatiotemporal resolution needed for the analysis for all health endpoints of interest. IHME makes national, and in some cases sub-national, disease rates available from their GBD Data Exchange and a simple query tool (http://ghdx.healthdata.org/gbd-results-tool). The WHO also makes national disease rates available from their Global Health Observatory.

Tools available for assessing health benefits of ambient and household air pollution mitigation

In recent years, multiple decision-support tools have been developed to automate and systematize the process of air pollution health impact assessment. Anenberg et al. (2016) reviewed several tools that have global scope, finding that the tools range in key characteristics, including spatial resolution, pollutants and health outcomes evaluated, and methods for characterizing population exposure, as well as tool format, accessibility, complexity, and degree of peer review and application in policy contexts. Nevertheless, many tools use common data sources for concentration-response associations, population, and disease rates, which drive much of the differences between estimated air pollution-attributable health impacts between analyses. These tools have been developed by the WHO, national agencies such as the US EPA, non-governmental organizations (NGOs), and academic institutions. Several are still operational and in more recent years additional tools have been developed.

As discussed previously, tools that are used to convert emissions to air pollution concentrations and from air pollution concentrations to air pollution health impacts are available with a range of complexity and data input needs. Two of the most commonly used full-form tools" are the WHO's AirQ+ and the US EPA's BenMAP-CE tools. Both of these tools estimate the effects of short-term and long-term changes in pollution using built-in sets of disease rates, population estimates, and concentration-response factors. They can be operated using concentration inputs from a variety of sources, including chemical transport model output, results of statistical models such as land use regression approaches, or monitor data. Users can also input their own datasets if desired. Both tools have extensive manuals and training materials. To estimate the air pollution-related health benefits of GHG policies, users of these tools need to estimate the impact on air pollution concentrations using an external approach, most commonly chemical transport modelling. Since chemical transport modelling is resource intensive and requires substantial technical expertise, this may be prohibitive for some analysis contexts.

By contrast, "reduced-form" tools are those that connect emissions to health impacts using built-in parameterizations, thereby bypassing the need to run computationally-intensive chemical transport modelling. Typically, reduced-form tools have built-in relationships between emissions and pollutant concentrations derived from chemical transport model simulations that were conducted during the tool's development. The LEAP-IBC is one such model that uses an existing database of emissions-to-concentration sensitivities to relate emissions from any location on Earth to average $PM_{2.5}$ and ozone concentrations for each country (Kuylenstierna et al., 2020). LEAP-IBC's emissions-to-concentration sensitivities were generated using the global chemical transport model GEOS-Chem (See **Section 7** for a case study describing the application of LEAP-IBC in Colombia). Fast Scenario Screening Tool (FASST) is another tool commonly used to relate emissions changes from one region to $PM_{2.5}$ and ozone concentrations in another region. FASST is driven by a region-to-region source-receptor matrix that describes the influence of emissions in one region on concentrations and health impacts in another (Van Dingenen et al., 2018). FASST's source-receptor matrix comes from global chemical transport model simulations using the TM5 model. Both LEAP-IBC and FASST provide rapid estimates of impacts of emission changes on $PM_{2.5}$ and ozone concentrations, attributable mortality, and crop yield damage. However, they do not provide information about where the change in air pollution-attributable mortality and crop yield impacts are occurring within the country. Tools are also available from ICAT's Climate action Outcomes and Mitigation Policy Assessment (COMPASS) toolbox. AIRPOLIM-ES is an Excel-based tool which estimates the health impacts of air pollution from electricity generation sources, including quantifying impacts on mortality and common respiratory and cardiovascular illnesses and can be used to quantify the health impact for different scenarios for existing and planned power plants. ICAT's TRACE tool is another Excel-based model that is able to quantitatively assess selected non-climate impacts of decarbonisation in the urban transport sector, and enables the building of an economic and social case for action, including the health impacts of shifts in local transport use through air quality improvements, as well as quantifying impacts on congestion, road accidents, and fuel use.

Often, equity considerations are a key aim of assessing air pollution-attributable health impacts from GHG mitigation policies. For example, it may be valuable to explore which population subgroups or neighbourhoods are experiencing disproportionate health impacts from air pollution, and which would experience improvements under mitigation policies. Most of the tools discussed in this section lack detailed approaches and data for assessing these distributional impacts. Estimated cases of air pollution-attributable lower respiratory infection, short gestational age, and low birth weight provide some information about impacts to children. Cardiovascular and respiratory health outcomes associated with air pollution are more common among elderly populations. Household air pollution disproportionately impacts women and children who are


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Household air pollution disproportionately impacts women and children who are exposed to combustion particles for longer durations throughout the day and are often responsible for collecting fuel and cooking.

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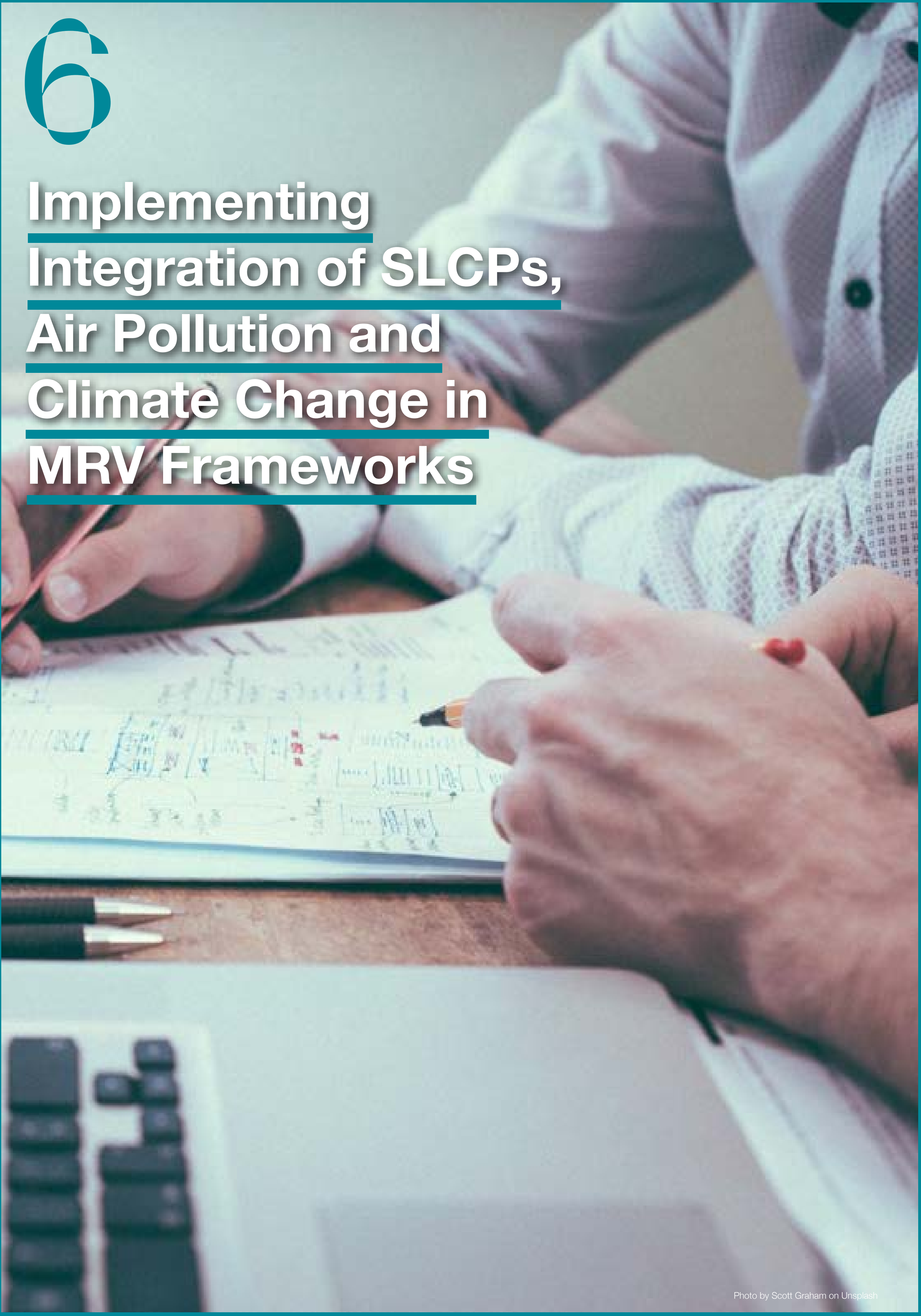
exposed to combustion particles for longer durations throughout the day and are often responsible for collecting fuel and cooking. To date, none of the tools directly consider socioeconomic status of the exposed populations. Full-form tools that provide information about how pollution concentrations are affected by emissions changes in a spatially explicit manner make it possible to explore distributional impacts, but as discussed previously are more computationally intensive and require specialized expertise to use. Discussing equity considerations qualitatively can highlight these issues and how they are affected by different policy choices when quantitative analyses are not possible.

Some GHG mitigation approaches may result in lower exposure to household air pollution (HAP). For example, interventions or policies that result in households switching to electricity or cleaner-burning fuels in lieu of burning unclean fuels (e.g., wood, dung, coal, and kerosene) for household energy needs would result in lower GHG emissions and lower HAP exposures. Estimating avoided mortality and morbidity from reduced HAP uses the same principles and general approach as for ambient $PM_{2.5}$. The attributable fraction approach is commonly used, with ambient concentrations in Equation 2 being replaced with HAP exposure levels. If HAP exposure levels before and after an intervention (e.g., measured values from an experimental study), these values can be used to estimate avoided cases of mortality and morbidity in that population. It is also possible to use estimation methods using the size of the population of interest, average household size, the percentage of households using unclean fuels, and approximate average indoor $PM_{2.5}$ concentrations with and without a particular intervention or policy.

Compared with ambient air pollution, fewer tools exist to estimate health benefits of reduced HAP. The WHO, as part of its Clean Household Energy Solutions Toolkit (CHEST), released the Benefits of Action to Reduce Household Air Pollution (BAR-HAP) Tool in July 2021 to assess costs and benefits of different interventions that aimed to reduce cooking-related household air pollution. BAR-HAP includes default data for all low and middle-income countries and allows users to define fuel and technology transition scenarios to explore costs and benefits of each. Users select from sixteen cooking device transition scenarios to analyse (e.g., traditional biomass or charcoal to transitional or clean fuels and technologies, kerosene to clean fuels and technologies, and one clean fuel/technology to another) and, for each transition scenario, from five policy interventions to consider (e.g. subsidy for stoves only, subsidy for fuel, financing, behaviour change communication, and technology bans). Results from BAR-HAP include the overall present value of social net benefits, costs per year, reduced morbidity and mortality, time savings, and reduced climate-forcing pollutants.

While BAR-HAP is a relatively complex Excel-based tool, the Household Air Pollution Intervention Tool (HAPIT) provides a web-based interface for rapidly assessing the health impacts of residential solid fuel combustion for household energy needs and the benefits of transitioning to cleaner burning technologies (Pillarisetti et al., 2016). The original HAPIT tool was developed using GBD 2013 integrated exposure response curves. It has since been updated with the Air Pollution Burden of Disease Explorer (ABODE) which uses GBD 2019 data (UC Berkeley, 2021). ABODE estimates health changes due to interventions designed to lower exposures to HAP of household members currently using unclean fuels (wood, dung, coal, kerosene, and others). Outputs include the number of deaths, disability-adjusted life years, years of life lost, and years of life lost due to disability associated with the intervention.



6

Implementing Integration of SLCPs, Air Pollution and Climate Change in MRV Frameworks

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Key messages

1 **Strengthening MRV frameworks to create an evidence base for integrated policy development for GHGs and air pollutants enables more effective mitigation action implementation and policy tracking.**

2 **Engaging with stakeholders early to understand requirements of any enhanced MRV system enables conceptualisation of future framework developments, additional output requirements, and more effective data flows and management.**

3 **Analysing any gaps in existing MRV frameworks given identified requirements enables the development of an improvement plan, which should be maintained and used to prioritise work across future years.**

4 **Enhancements to MRV frameworks are not immediate: an approach of continuous improvement and investment in priorities that better enable effective climate and air quality action adoption and tracking is recommended.**

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MRV frameworks are a core element of international climate change reporting under the UNFCCC. MRV frameworks establish an evidence base for decision making and information sharing to enable effective climate action. This includes regular collection and analysis of reliable information on GHG emissions and trends, climate action, and support provided or received. The ETF under the Paris Agreement builds on previous MRV arrangements. Utilising these frameworks to better understand air pollution is a logical step, and would create a more effective system of reporting and planning, providing evidence bases for international climate change reports, reporting on progress towards SDGs, development of national and local air quality management plans, and updates to NDCs.

Guidance on developing MRV frameworks is already widely available and comprehensive, including the UNFCCC's 'Handbook on institutional arrangements to support MRV/transparency of climate action and support'. The Handbook provides a nine-step plan for setting up and adapting institutional arrangements for climate transparency. In this section, we elaborate the same nine-step plan to provide practical steps and advice for the integration of air pollutant and SLCP thematic areas into the climate MRV system. Completing all nine steps will take time and resources. Work to implement will require continued development of existing systems, but small progress on any or all of these steps can significantly and directly contribute to a more robust MRV framework. This will maximise the availability of data and knowledge of GHGs, air pollutants and SLCPs, inform decision making on policies and actions as well as aid transparent reporting. Information in this section is complementary to the information presented elsewhere, and focuses on organisational guidance and a stepwise approach to setting systems up. This section is targeted towards organisations and individuals that build and/or coordinate long-term technical teams, data flows and stakeholder engagement activities for air pollution and GHG inventories, projections as well as policy analysis and development.

A functioning and effective MRV system is built on appropriate governance, emissions and sectoral policy expertise, clear data flows, effective systems and tools (commonly IT but also stakeholder engagement and reporting tools), and engagement with stakeholders, including policy makers or data providers. Together, these can be used to build a robust evidence base for decision makers. Typically, stakeholders involved in climate MRV systems can be broadly categorised as one (or more) of:

Data collectors and providers – agencies, organisations, or companies that collect data which can be used in the development of an evidence base for inventory compilation, projections, and policy development.

Inventory and projection experts – typically sectoral experts who have intimate knowledge of their sector in their countries, the data sources used to develop the evidence base, likely shifts in emissions profiles and the policies that would impact emissions of GHGs and air pollutants

Users of the evidence base – policy and decision makers or agencies requiring outputs from inventories and projections analyses to meet international and regional reporting obligations, reliant upon the analysis and evidence collected and analysed by others in the MRV system. Other users can include those that have no direct control over climate action development, such as companies or citizen groups, that may use the outputs of the inventory and projections to better understand their own contributions and develop actions and strategies of their own.

Governance and steering committees – those responsible for the maintenance of MRV systems, who have strategic input and oversight. Ensuring that data flows are robust and that institutional arrangements are up-to-date and formalised, and that the outputs continue to satisfy the needs of their users.

All stakeholder groups should be considered, and realistic timelines established during the development of more robust MRV frameworks. A well-functioning team, high quality data flows and transparent reports will take several years to establish. Real-world examples and best practice can be used as reference points, particularly for when countries are at the early stages of MRV system development. Regardless of the starting point, the guidance in this section should be used to identify early first steps that can be taken before gradually advancing towards a more comprehensive framework.

The box below describes efficiency improvements identified by South Africa following a recent study to integrate their air pollutant and GHG data gathering and analysis. This further illustrates the benefits of integrated air pollutant and GHG inventories to produce high quality transparent evidence (See **Section 7** for further details).

Case study South Africa - Analysis of the Potential Benefits of Integrated Air Pollutant and GHG inventory systems (2021)[2]

A recent study in South Africa sought to integrate their air pollutant and GHG data gathering and analysis through the development of a coherent MRV system. The resulting MRV system brought numerous efficiency improvements in reporting on climate change and air pollution for users in South Africa. In particular, improvements were identified for the preparation of:

- **International climate change reports** submitted to the UNFCCC (NDC, NC, BTR, NAP etc.).
- Annual Climate Change Reports and other public facing material (e.g. websites) produced by the ministry responsible for environment (DFFE).
- Annual National **Assessment of the State of Air Quality** at national and local levels.
- Reviews and updates on the climate focused - NDCs and **air pollution** focused – national and local Air Quality Management Plans (AQMPs).
- **SDG** reporting particularly focussing on SDG 3 – Health and wellbeing and SDG 13 – Climate change but also linking to co-benefits and conflicts of climate and air pollution action for most other SDGs.
- Data and information for the **South Africa Air Quality Information System (SAAQIS)** for use by analyst and decision makers.
- Providing a more **integrated view of development projects** with quantified co-benefits (for air quality) within the climate change response database and potentially for any development strategies and projects (e.g., energy, transport, infrastructure).

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[2] Case Study of the Development of South Africa's Climate Change Monitoring, Reporting and Verification (MRV) system and mainstreaming of air quality considerations

The benefits of integrating air pollution and climate change into MRV systems have been documented in previous sections, and remain the same here, namely that enhancements in the national environment evidence base can be made whilst making data gathering, quality assurance, and analysis activities more efficient, and ensuring that reporting and methods used in inventory and projection analyses are consistent and comparable.

Despite the above benefits, significant challenges to integrating GHG and air pollutant inventories exist. For example, there will often be **conflicting technical priorities between GHG and air pollutant inventories and no national MRV system is likely to be the same as another.** The competing need to consider air quality on a local scale and GHG emissions and climate adaptation nationally mean that the systems and actions to improve air quality often have different spatial, temporal, and sectoral focuses to those developed for climate mitigation strategies. For example, as the Santa Rosa case study in **Section 7** illustrates, cities are both responsible for the majority of greenhouse gas emissions and also hotspots for poor air quality with the greatest levels of exposure. Considering MRV framework development on a local scale that can feed into national MRV frameworks can help create a full understanding of the priorities on all spatial scales.

The balance of these considerations is country-specific and will depend on, amongst other factors, the locations and relative contributions of key sources, data availability and quality, and the institutional arrangements for environmental data collection and analysis. Therefore, no national MRV system is likely to be the same as another, with each requiring a bespoke design to account for differing national circumstances.

In addition, there will be many political and organisational hurdles to overcome. Integrating air pollutant and greenhouse gas inventories can often be considered an organisational change management challenge. With the need to integrate teams, merge data, and train experts and the associated impacts that these changes bring. The disparate nature of existing stakeholders, operating in different governmental departments and agencies, can introduce barriers to the integration of different thematic areas into more centralized national policy and decision support tools. Communication and "joint working" between stakeholders with different primary objectives/remits can often be a problem and the systems need to bridge differences to incorporate and not disband existing pockets of expertise, good practice and valuable data flows. This is especially true when attempting to integrate teams and people who already have limited capacity and time to work on existing sets of tasks.

Photo © Getty Images
Harry Wedzinga

Plan for setting up and adapting institutional arrangements – practical advice for integration of climate, air pollutants and SLCPs into MRV systems

This nine-step plan is intended to provide a practical approach to developing an integrated MRV system to improve understanding, use, and effectiveness of action to reduce emissions of GHGs (including SLCPs) and air pollutants. It is important to recognise that through undertaking these steps, the evidence base will improve, priorities may shift, and changes to the MRV structure may be necessary. Rather than a prescriptive guide, the nine-step plan is intended to be an iterative process to move towards a fully integrated system and refinements made through better understanding should be considered a key component of the process and its eventual success. The listed steps and activities are intended to be generic but will inevitably vary in relevance for different countries on the basis of national circumstance. In addition, these steps do not need to be consecutive, and work can be made on several steps in parallel.

Scoping

Before beginning the nine-step plan, a scoping phase is necessary, focusing on understanding the demand for the transparency system, in particular the user requirements and how the evidence base will be used once fully developed. This helps determine priorities and resources required to offer sufficient information to ensure the policy makers are able to make effective and well-informed decisions. Factors that affect the sophistication and resource needs for the integrated system include:

1. The extent of the air pollution problems, (e.g., wide-spread and severe, small pockets of concern or broadly little concern) and
2. The need for more complex policy analysis for air pollutants and GHGs that may require greater data resolution or consideration of other social, economic, and environmental considerations.

Developing a strategic plan that outlines the expectations of the integrated evidence base ensures mutual understanding of eventual system requirements and can help clarify the processes in later steps.

Step 1

Engage users and clarify the scope, outputs and legal frameworks

The first step is to engage with relevant stakeholders working in climate action, environmental protection, and health. This should not be limited to stakeholders already involved in any existing MRV system, such as policy makers or agencies responsible for the collection of environmental statistics, but should seek to incorporate a broader group of stakeholders to understand how the inventory and projections system is used. For example, private companies, charities, agencies responsible for local air quality management or climate groups may use outputs from the current inventories and their projections to enable for the development of their own plans and strategies to mitigate their impact on the environment.

Maintaining a log of interested stakeholders with information on main objectives is a useful reference tool for MRV development and can help to highlight the broad scope and benefits of planned work to integrate air pollutants and GHGs into a single framework. This also enables a list of outputs from the transparency framework required, including what air pollutant and GHG related information, in what form, and also the frequency of updates needed.

It is important to clarify the institutional arrangements to define the roles and responsibilities for the production of outputs. Overarching legal frameworks can help clarify the need for these arrangements. For example, meeting UNFCCC reporting requirements is a necessity for all countries and arrangements should be formalised to enable for the regular and reliable production of outputs that satisfy these requirements. However, it is important to explore beyond these basic needs to understand if there are more complex needs to enable decision making, public and private engagement in climate and air quality engagement, and/or policy tracking. For example, needing to understand the trends and levels of pollution in cities, key or politically important sources of emissions over different timeframes may require the development of data sources and flows, and clarifying responsibilities for the data flows is an important step to meeting this demand. Other outputs can include various types of sectoral (e.g., energy, transport, health, industrial) and thematic (e.g., sustainable development, local air quality management, GHG policy development) strategies. Outputs can also include a public facing website to track trends in historic emissions as well as contributing to national statistics publications.

Step 2

Establish required draft organisational structures, data flows, and improvement plan for an integrated air pollutant and GHG MRV system

Once the ideal requirements of an enhanced MRV system have been clarified, it is important to compare this against existing arrangements. This enables the identification of data or expertise gaps, where relationships need to be more formalised through legal frameworks, and missing outputs. These can form elements of an **improvement plan** which identifies specific improvements needed to achieve outputs with a judgement on priority and estimates of efforts, costs, and resources needed to implement them.

Existing and required MRV systems can be expressed through flow charts which offer a graphical view of the responsibilities and roles of stakeholders involved in the system, and how information and data flows through it. Comparison analysis of the flow charts of the required and existing MRV systems can identify:

- Required expertise, coordination, data flows, and tools to meet user requirements for the MRV system.
- Experts, systems, and datasets that are already in use and have mandates and resources already assigned.
- Gaps and highlight improvement needs to fill these gaps by building on the improvement plan. **Sections 3 and 4** of this guide provide reference material for national officials as they work to identify both political and technical gaps in their existing national systems.
- Whether existing climate-related outputs (GHG inventory reports, BURs/BTRs, NCs) lack the detail or scope required for providing transparency on SLCPs and air pollutants and on wider impacts (e.g. on human health and ecosystems) . All options to fill current reporting gaps should be identified.

Expertise gaps may take time to fill, whether through recruitment strategies or through investment in training candidate experts at relevant agencies. Any emerging data needs should be documented in the improvement plan and investment to expand existing datasets, or to develop entirely new data collection activities should be prioritised based on the importance of the outputs that will depend on these datasets.

Once this gap analysis has taken place, a second round of engagement with stakeholders from all different groups is an important part of this step. Existing experts and data providers should be engaged with the assessment and understanding of existing building blocks, gaps, and then to elaborate the improvement plan to highlight priority development needs. This engagement would maximise collaboration, identify potential hidden challenges from previous experience, and ensure the proposed improvements are both tractable and would resolve gaps adequately. In addition, the users of the MRV system and stakeholders that can provide funding should be engaged to communicate the resources required for the integrated MRV and inventory system development and to prioritise improvements and plans for development. This evidence gathering and stakeholder engagement is crucial to generating support from all decision makers and officials, providing clarity of the benefits to them and to the policy making process of an integrated system.

A clear picture of the integrated air pollutant and GHG MRV system should be presentable as a draft organisational diagram and data flow diagram. An organisational diagram highlights the interactions between the various organisations involved, steering committees, coordinators, experts, data providers, and policy makers. Circulating this draft organisational structure amongst stakeholders would ensure clarity of respective roles and responsibilities. Figure 14 illustrates an example of an organisational diagram. Diagrams showing data flows can help to illustrate to stakeholders where data flows from and the outputs that rely on it and the data processing needed.

Step 3

Generate high-level governmental support to drive progression towards integrated MRV system development

Step 3 and Step 4 focus on generating high-level support to oversee the development of the integrated MRV system that meets the needs of stakeholders identified in Step 1. Building teams with clear leadership, roles, and mandates to progress the development of the system and manage its sustained and continuous improvement is an important element of the MRV system. Step 3 involves identifying and gaining high-level governmental advocates to ensure momentum is maintained throughout the system development. In particular, engaging individuals in senior positions with responsibilities including climate change, air pollution, or climate finance, could aid the continued support and resource availability for the development and sustained implementation of an integrated MRV system. National focal points for climate and for air pollution should seek to engage and include high-level leaders in the development of strategies, illustrating at each stage the benefits of an integrated system for improved transparency, evidence-based decision making, and cost-effective action implementation.

Working from the national focal point upwards can be a difficult and iterative process. External international high-level support can help to get the attention of high-level governmental advocates. To assist with this, the development and customisation (to national and subnational situations) of evidence supporting an integrated MRV approach can be gathered and presented, including:

- **Illustrative timelines for international reporting, progress tracking and decision making** can help to illustrate the pressing need for the development of systems.

- **Case studies of the mobilisation of investment in green economy, health improvement and adaptation,** through improved transparency systems will help to assess value, in monetary terms, the development of integrated AP and GHG inventory systems.

This supporting evidence and reasoning can be reused throughout the development and ongoing day-to-day stakeholder engagement, to present the value of an integrated MRV system.

Figure CS - 1

Organization chart outlining the proposed key functions of Montenegro's MRV system organizational structure

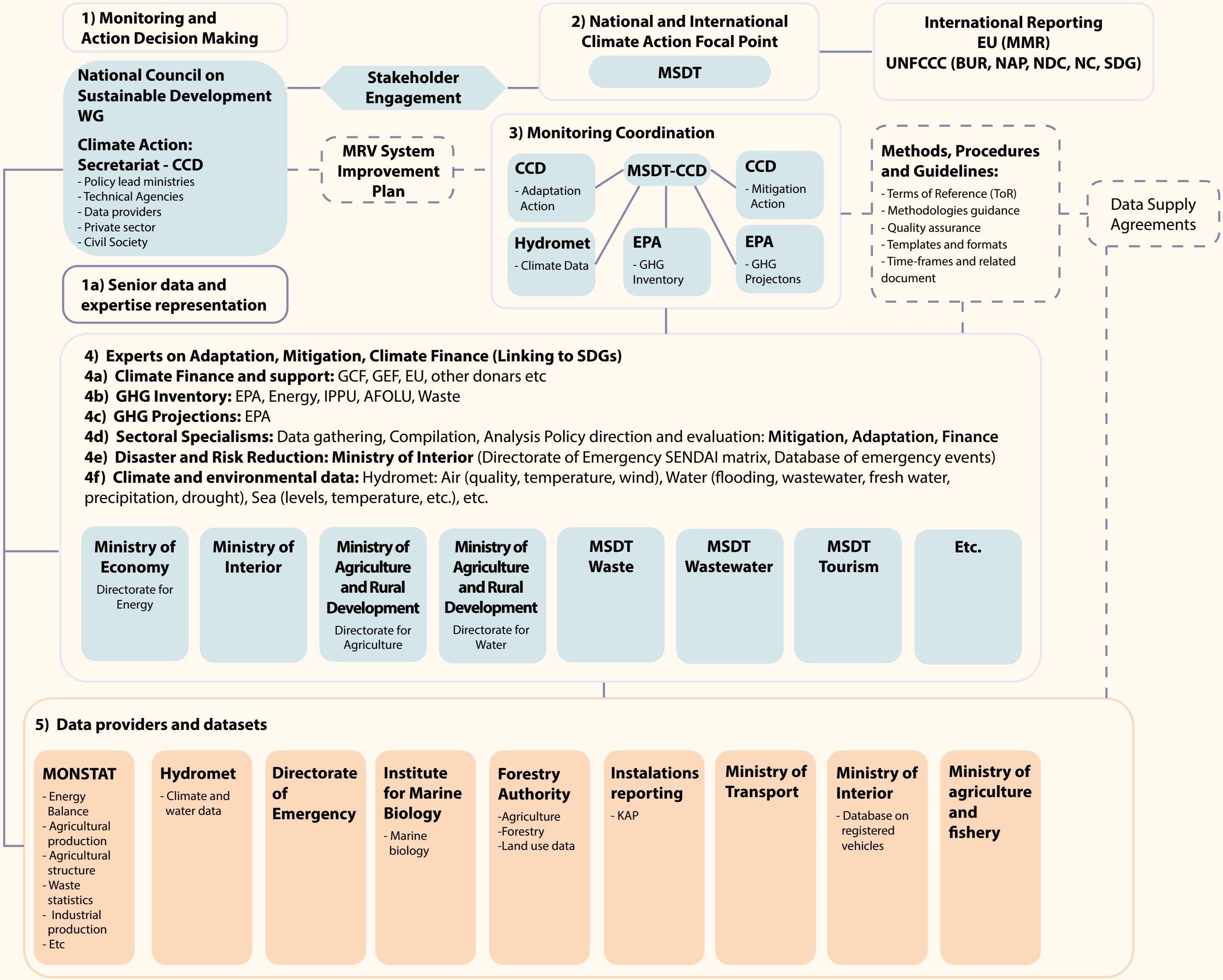


Figure 14: Example organisational diagram

Step 4

Establish high-level steering and coordination functions

Whilst Step 3 focussed on identifying high-level advocates for the integrated inventory and MRV system, Step 4 seeks to establish a balanced advisory team who steers the outputs and inputs to the system of and technical coordination that can manage the different data providers and experts. Step 4 includes the following activities:

- **Identify and assess the quality of existing coordination mechanisms** for national transparency systems. There may be well-functioning, existing coordination mechanisms in place as identified in Step 2. In these cases, the existing coordination mechanism can be built upon and fine-tuned to the specific needs and requirements outlined in the improvement plan. Coordination mechanisms typically take the form of **bodies, steering committees, and/or working groups**. If these are not in place, or are not functioning well, this is an opportunity to launch/relaunch and engage/re-engage the involved networks and institutions. The national focal point (on climate and air pollution) will need to decide whether additional networks should be integrated into existing coordination activities, or whether new coordination activities are required.

- **Establish terms of reference for the coordination of any new activities/ steering bodies** to ensure they are properly informed by the transparency system and contribute to improving it by using resources and/or data.
- **Introduce the coordinating teams to the draft material developed in Steps 1 and 2** to highlight the stakeholders, outputs, datasets, improvement plan, organisational diagram, and data flows of the proposed integrated system.

Case studies of countries developing and using integrated GHG and air pollution inventory and MRV systems, as provided in **Section 7**, can be a useful reference tool to understand their coordination and steering committee demographic.

Step 5

Refine and draft out the proposed working arrangements

Once high-level governmental support is aligned, coordinators have been identified and steering committees and working groups have been set up, the national focal point and coordinators can start to fully elaborate the integrated system arrangements, the overarching organizational structures and the key roles and responsibilities within it. Fully elaborating and documenting the organizational diagram, stakeholder list, outputs and an inclusive improvement plan drafted in Steps 1 and 2 will help to clarify the scope of the mandate of the institutional arrangements for the integrated air pollutant, SLCP, and GHG MRV system. This exercise can be supported by a series of one-to-one or thematic engagements with key organisations or organisational groups to agree roles and responsibilities, as well as the resources needed to perform them.

This step will draft defined roles, responsibilities, and activities for:

- The **technical coordination activities / working groups and key personnel** who will carry out the required additional data compilation and management for air pollutant and SLCP integration.
- The **existing and additional data suppliers** that will organise, plan and execute the data gathering needs for air pollutant and SLCP inventories and scenario assessment that are not currently available directly from the existing climate-focused framework(s) (see **Section 3**).
- The **team of national experts needed for compiling and reporting additional information** on air pollutants and SLCPs.
- **Organizations that will use the inventory data for analysis and modelling** (including health experts/professionals) and therefore benefit from a regular supply of information from the transparency system.
- **The outputs** produced, for who and when, meeting requirements identified in Step 1.
- **Maintaining and overseeing the implementation of the improvement plan** built in Step 2 for further development of the integrated system and its outputs.
- **Steering committee and advisory/ executive** responsibilities for directing

Figure 15: Example roadmap/implementation plan.

Improvement ID	Improvement title	1 2021 BUR completion	2 2022 re-establishment of the National Council	3 2022 Annual GHG inventory	4 2022 Low carbon development strategy	5 2023 additional EU GHG inventory reporting requirements for LULUCF come into force	6 2023 EU climate and energy union reporting on mitigation policies and measures, projections and adaptation actions	7 2023 NAP completion	8 2024 National Communication and BTR	9 2025/6 NDC update
CC1.1	Mandate for National Council, working group on climate adoption and mitigation and MRV system steering committee									
CC1.2	Update of the existing rulebook for Climate Change MRV systems		■							
CC1.3	Integrate Committee of REGULATION)EU) 2018/1999 Governance of the Energy Union and Climate Action regulation into the MRV system		■							
CC1.4	Prepare for implementation of LULUCF Regulation						■			
CC2.1	Establish National Support and Climate Finance Tracking Team					■				
CC3.1	Develop an Annual Data Collection Plan for the MRV system								■	
CC4.1	Establish Formal QA/QC Objectives and quality system for the MRV system						■			
CC4.2	Support the development and mainstreaming of climate consideration into Sector-Level Strategies						■			
CC4.3	Develop an NDC Implementation roadmap				■					
CC4.3.1	Additional improvements to tracking climate action				■					
CC4.4	Map investment Needs for Actions Against Funding Sources									■
CC5.1	Progress tracking updates for the National Council and other national decision makers		■						■	
A1.1	Evaluate implementation of the 'Law on the Protection against Adverse Impacts of Climate Change'							■		
A1.2	Improve Adaptation Institutional Arrangements							■		
A2.1	Expert development, training and mentoring for MRV coordinator for Adaptation							■		
A3.1	Set up Adaptation Data-Supply Agreements							■		
A4.1	Develop Adaptation tracking MRV Work Plan							■		
A4.2	Develop and maintain a list of Nation Adaptation actions for the NAP, NDC, NC, BTR and other publications.							■		
A5.1	Engage with Public on Climate Change adaptation and resilience issues							■		
M1.1	A sustainable and continuously improving GHG inventory			■						
M1.2	A sustainable and continuously improving approach to tracking and quantifying action and modelling GHG projection scenarios.				■					
M2.1	Increase GHG Inventory Team			■						
M2.2	Establish a team of experts and or ToRs for experts on mitigation actions (PAMs) and projection scenarios				■					
M3.1	Set up Mitigation on Data-supply Agreements						■			
M3.1.1	GHG inventory data flows			■						
M4.1	Develop Mitigation tracking MRV Improvement Plan				■					
M4.1.1	Maintain a GHG Compilation Improvement Plan as part of the overall MRV system improvement plan			■						
M4.1.2	GHG inventory calculation systems			■						
M4.1.3	Improve GHG Key Category Assessment and Uncertainties			■						
M4.1.4	Move to Higher Tiers of GHG Inventory Sectors			■						
M4.1.5	GHG Inventory NIR improvement			■						
M4.1.6	GHG Inventory reporting tools (CRF)			■					■	
M4.1.7	GHG Inventory quality systems						■			
M4.1.8	Integrating LRTAP and GHG Inventories				■					
M4.2	Develop and maintain a list of mitigation actions and indicators for the NDC, LTS, NC, BTR and other publications				■					
M4.6	Establish a process and modelling tools for GHG projections scenario updated				■					
M4.7	Support to Low-Carbon Development Strategy 2050 development								■	
M4.8	Prepare for 1st Biennial Transparency Report	■								
M4.9	Peer review of the BUR GHG inventory, projections and mitigation actions		■							
M5.2	GHG inventory, projections and mitigation action stakeholder engagement									
		1	4	9	8	1	5	7	4	1

the inventory work as identified in Step 4. Deciding on which organisations should be involved in this steering activity and their roles and responsibilities.

Step 6:
Develop an implementation plan

An implementation plan identifies the practical steps, activities, timings, milestones and investments (resourcing) needed for the air pollutant, SLCP, and GHG integration at the national level.

The implementation plan should:

- Identify the revised/new legal arrangements needed.
- Outline the desired plans for recruiting and training experts.
- Develop and/or adjust the key national data systems and data flows.
- Develop systems and tools to manage the data flows and support experts and coordinators.
- Establish a communication and engagement strategy to stay in touch with and get buy-in from stakeholders.

Typically, at least some elements of a functioning data system will already be in place to satisfy UNFCCC climate reporting requirements and/or air quality assessments, although these may not be formalised. For example, data providers (at present to be engaged on an ad-hoc basis, rather than regularly and reliably providing data to inventory agencies). Engagement with these stakeholders to formalise relationships can therefore establish more regular engagement and involvement in the inventory and projections framework. It may also be possible and more efficient to expand and/or merge existing data systems to handle the additional pollutants and profiles (such as activity data and emission factors) rather than to develop entirely new systems, tools, expert teams etc. Where data management systems do not yet exist, use of existing data management systems used in other countries can be a helpful first stage, seeking external support for this step (e.g., from ICAT) as necessary.

The development of the implementation plan presents an opportunity for the national focal point and coordinators to review the success of existing data models and systems, and to suggest improvements needed to better inform cross sectoral, public and private decision makers on embedded air and climate action. The implementation plan should be as specific as possible in relation to the gathering, processing and analysing of data, recruitment and training of experts, development of tools and engagement activities.

An example component of an implementation plan from Montenegro is presented below covering the full mitigation, adaptation and support MRV scope under the Paris Agreement and will be presented in Montenegro’s latest Biennial Update Report (BUR). This table highlights key improvement activities planned for each of the key Paris Agreement Transparency outputs identified over the next six years as a part of developing and adjusting key national data systems and data flows.

Resource and capacity constraints mean that any existing pool of expert networks and practitioners are rarely able to accommodate all aspects of the implementation plan. Instead, additional capacity and resources will need to be identified and quantified in support of the implementation plan. The UNFCCC Handbook (Table 3, p.36) provides a useful framework that can be used to identify resource need.

Figure 16 on the next page provides an overview of a sample integrated system showing details of governance, experts required, data-flows, systems, tools, stakeholder engagement and estimated resource needs for the different functions of integrated inventory work. This assumes an annual update process is in place and ensures the full engagement and continuous development of expertise and improvement of the system.

Figure 16: Integrated inventory system development and resource plan.

	Institutional Arrangements (√= functioning as planned, • = Started development, X = not established yet)					Resource needs (highlighting what resources are needed to manage a sustainable production of continuously improving integrated inventory outputs). Does not include AQ modelling.					Comments to help tune institutional arrangements and resources.
Thematic Area	Governance	Expertise	Data Flows	Systems & Tools	Stakeholder Engagement	Number of people	Workload (% of time)	Full Time Equivalent (FTE)	FTE for backup and succession (+30%)	Total FTE	
Climate greenhouse gas and air pollutant trends, projections and mitigation action.											
Greenhouse gas and air pollutant trends	√	√	√	√	√	17		8	2	10	
Coordination	√	√	√	√	√	2.0	0.5	1.0	0.3	1.3	Planning and QA/QC of AP and GHG inventory outputs. Liaison with stakeholders and compilation experts. Leading on reporting and continuous improvement. Ensuring adequate resources are available.
Large reporting industry	√	√	√	√	√	2.0		1.0	0.3	1.3	
Electricity generation	√	√	√	√	√	0.5	0.5	0.3	0.1	0.3	Gathering, interpreting checking and integrating reprted data (e.g. from regulatory frameworks and/or PRTRs) for a complete national estimate. Reconciliation with national statistics and GHG/AP methods requirements.
Energy extraction and production	√	√	√	√	√	0.5	0.5	0.3	0.1	0.3	
Industrial manufacturing (e.g. chemical,steel, cement, etc)	√	√	√	√	√	1.0	0.5	0.5	0.2	0.7	
Diffuse stationary energy use	√	√	√	√	√	1.0	0.5	0.5	0.2	0.7	Usually national statistics based with additional detail on small/medium sized heat and power generation technologies (e.g. types of boiler/heating/power systems) and fuels used).
Diffuse non-energy emissions (processes and product use)	•	•	•	•	•	1.0	0.5	0.5	0.2	0.7	Survey based analysis reconciled and combined with national production and consumption statistics.
F-gas emissions	√	√	√	√	√	1.0	0.5	0.5	0.2	0.7	
Transport	√	√	√	√	√						
Road Transport	√	√	•	•	√	2.0	1.0	0.8	0.2	1.0	
Engine emissions	√	√	•	•	√	1.0	0.5	0.5	0.2	0.7	Complex and integrated road transport modelling. Integrated road and vehicle characteristics with national energy consumption statistics. Development of spatial and temporal models for AP and AQ modelling.
Evaporation losses	√	√	•	•	√	0.5	0.3	0.1	0.0	0.2	
Brake, tyre and road wear	•	•	•	•	•	0.5	0.3	0.1	0.0	0.2	
Aviation	√	√	√	√	√	1.0	0.5	0.5	0.2	0.7	Airport by airport estimates including take-off and landing emissions separated from cruise. Spatially disaggregated emissions needed for AP emissions and AQ modelling.
Shipping	√	√	√	√	√	1.0	0.5	0.5	0.2	0.7	Port by port estimates including entrance and exit and in port emissions separated from international routes. Spatially disaggregated emissions needed for AP emissions and AQ modelling.
Non road mobile machinery	•	•	•	•	•	0.5	0.5	0.3	0.1	0.3	Analysis of different types of equipment and technologies and combustion conditions. Reconciliation with national energy consumption statistics.
Agriculture	√	√	√	√	√	2.0	0.5	0.5	0.2	0.65	
Livestock	√	√	√	√	√	1.0	0.3	0.3	0.1	0.3	Development of nitrogen and carbon flows within agricultural systems. Agricultural statistics with insights into feed composition and crop lifestyles.
Crops	√	√	√	√	√	1.0	0.3	0.3	0.1	0.3	
Landuse, landuse change and forestry	√	√	√	√	√	2.0	0.5	1.0	0.3	1.3	Landuse and forestry inventories and mapping. Analysis of 'natural' emissions from range of different growing and dynamic natural systems (seas, forests, deserts and other lands).
Waste	√	•	√	√	√	1.0	0.5	0.5	0.2	0.7	Combining national statistics and wast facility level reporting and analysis. Waste composition analysis and estimation of un-planned and un-wanted events e.g. fires and unauthorised waste burning.
Greenhouse gas and air pollutant projections						...	...	...	...	...	
Greenhouse gas and air pollutant mitigation action						...	...	...	...	...	
Climate risks, vulnerabilities and adaptation action											
Climate risks and vulnerabilities						...	...	...	...	...	
Climate adaptation action						...	...	...	...	...	
Climate finance and support for mitigation and adaptation											
Climate finance and support for mitigation						...	...	...	...	...	
Climate finance and support for adaptation						...	...	...	...	...	
Wider impacts of climate action											
Wider national growth and development impacts of action						...	...	...	...	...	
Social groups and cohesion - e.g. gender, backgrounds						...	...	...	...	...	
Wider SDG impacts of action						...	...	...	...	...	

Step 7

Develop the legal framework for the integrated inventory to be able to sustain its activities

Developing legal frameworks takes time and requires legal advice on integrating specific needs into broader national governance frameworks, existing memorandum of understanding, and terms of reference. In many countries, both the air quality and climate agendas have established specific air quality and/or climate response laws that build in data gathering and analysis and create the mandate for integrated air and GHG inventories.

This step includes the following activities:

- **Review arrangements that already exist for climate and environment** and assess how the needs of the integrated air and GHG inventory system can be integrated into these existing arrangements or start to design amendments or new laws and agreements.

- **Pass any new and existing institutional arrangements into laws** - Clearly defining planned/proposed working activities, data collection, expert teams, systems and tools, will enable coordinators, supported by high-level governmental leaders identified in Step 3, to more readily pass institutional arrangements into laws, and develop formal arrangements between organisations with terms of reference and resource needs acknowledgements.

- **Formalise agreements with data suppliers** - Data suppliers will need a mandate to supply data, especially if it is a customised output and a regular/cyclical requirement. They will also need to be engaged in continuous improvement where appropriate and therefore potentially changing requirements and resource needs. Data supply agreements (even if not legally obligated) provide some formally agreed approach to making data available for the integrated system. It may be possible to adjust existing legal frameworks rather than requiring new national legislation for the integration of air pollutants and SLCPs into the climate MRV system. It is likely that barriers and challenges will emerge, such as ensuring the confidentiality of data, methods of providing data and agreeing on legal terms and governance.

This work can be ongoing alongside work on developing integrated inventory estimates if there is funding to do this initial content work (updating and estimating GHG, SLCP, and air pollutant emissions) before legal frameworks are established.

Step 8

Establish structures, systems and tools for long-term sustainability and efficiency

While the overarching governance, team, and data flows are being formalised, coordinators (if sufficiently resourced) can begin to develop the IT systems needed to support an efficient integrated inventory system. These systems and tools can assist with coordination of data and expertise, developing workplans, prioritisation, and setting output objectives on any ongoing work to develop national strategies and reports. The systems and tools can also offer insights on air pollutant, SLCP, and GHG trends, projections, and provide means to more efficiently draft international reports including BURs, BTRs, NDCs etc. The management approaches and resources for this include:

- List of **outputs**, timelines and resource needs associated with developing these outputs that can be used to highlight priorities, discrete objectives and shared underlying datasets and update activities (developed across Step 1 and Step 2).

- The **improvement plan** with statuses, timelines and resource needs which can be used to prioritise development of expertise, tools or data collection and act as a focal point for logging future development needs (developed across Step 1 and Step 2).

- The list of **stakeholders** identifying data providers, experts, and output users, as identified in Step 1 and with any gaps identified in Step 2. This provides a readily available registry of who is who, as well as who could be drawn on to support the varying strategy development activities.
- The list of **datasets** linked to outputs. This identifies the critical datasets and enables coordinators and technical experts to consolidate and coordinate data collection activities and data flow improvements (previously identified in Step 2).
- **Data collection** tools and templates. Specific data collection tools including webforms, shared directories and databases, web access and Application Programming Interfaces (APIs) can be developed to facilitate data collection and new data generation.
- **Data analysis models and tools** for more complex sector estimates and for policy analysis. The development of these tools should be prioritised on the basis of sector importance to GHG and/or air pollutant emissions and from discussions with policy makers and other users of the environmental data incorporated into the integrated system.
- **Aggregation databases** to collate estimates compiled in different tools/models into consistent and transparent tools for wider use.
- **Systems for disaggregating national estimates** and mapping them at smaller spatial resolution for subnational engagement and air pollution modelling.
- **Documenting methodologies** and developing **expert training material** that ensures updated estimates can be prepared on a regular basis with continued improving quality.
- Establishing **quality objectives** and plans and procedures for quality assurance and quality control (QA/QC).
- Tracking outputs, managing workplans, the evaluation of status of quality of systems and assessment of the overall functionality of the integrated framework.

Details of outputs, the **improvement plan**, details of **stakeholders** and **datasets** will have all been drafted in Step 1 and Step 2 to orientate early development of the integrated system and can now be further elaborated by coordinators with input from relevant stakeholders.

These systems and tools can be used by coordinators to help fine tune the legal basis and **governance** for the integrated system. Identification of specific organisations, their roles and individuals tasked with undertaking certain activities through the list of stakeholders will facilitate the clear engagement of contributors and help to identify gaps in **expertise** or **data flows** provision.

Through this work and the generation of targeted outputs, greater information will become available to support continuous improvement and the enhancement of climate- and air quality-focussed reporting. In particular, knowledge of the spatial and temporal emissions of SLCPs and air pollutants will be considerably strengthened through the design and implementation of tools that quantify emissions of pollutants including methane, HFCs, BC, and other air pollutants. Additional, or new national reporting on the wider impacts (particularly related to health) of combined GHG and air pollutant measures will also be possible and can be planned for, for which guidance is provided in **Section 5**.

The work here on implementation can be a focus for the steering committee identified in Step 4, using their input to prioritise the implementation of the improvement plan and their help in securing resources to do it.

Photo by the Climate Reality Project on Unsplash

Step 9

Continuous improvement and evolution of the integrated MRV system

The developed integrated air pollutant, SLCP, and GHG MRV system will be continually evolving, with improvements over time to its data, expert insights, how it engages with stakeholders and decision makers and its ability to report. The system will be regularly producing outputs for a range of different stakeholders and reporting requirements.

To support this process, regular activities to bring stakeholders together should be established either through steering committees, working groups, or by other means. Engagement activities should be timed appropriately around the phasing of inventory updates and the need to plan specific improvements prior to those updates being made and to peer review the latest updated versions.

Engagements should:

1. **Update stakeholders on the latest evidence** developed and managed by the system. In this case, the air pollutant and GHG inventory trends and other outputs (maps, policy tools, emission factors etc), the latest changes to methods, data sources and assumptions and their implication for decision making.

2. Engage with stakeholders to **prioritise improvement**s for future updates, understand the resource needs for these updates and sources of funding. Priorities can be identified through discussions with primary users of data such a policy-makers; through international inventory review and additional recommendations of thematic/data experts. Other stakeholders would need to be included in discussions when appropriate. For example, where different data is required to be collected or reported with greater resolution, discussions should include data suppliers to understand the feasibility of improvements, timelines for implementation, and to formalise any new data sharing agreements as per Step 7.

This is a cyclical process that can be facilitated with pre-planned regular meetings. The inventory coordinator should manage the technical components of this engagement while national focal points facilitate and lead the stakeholder engagement.

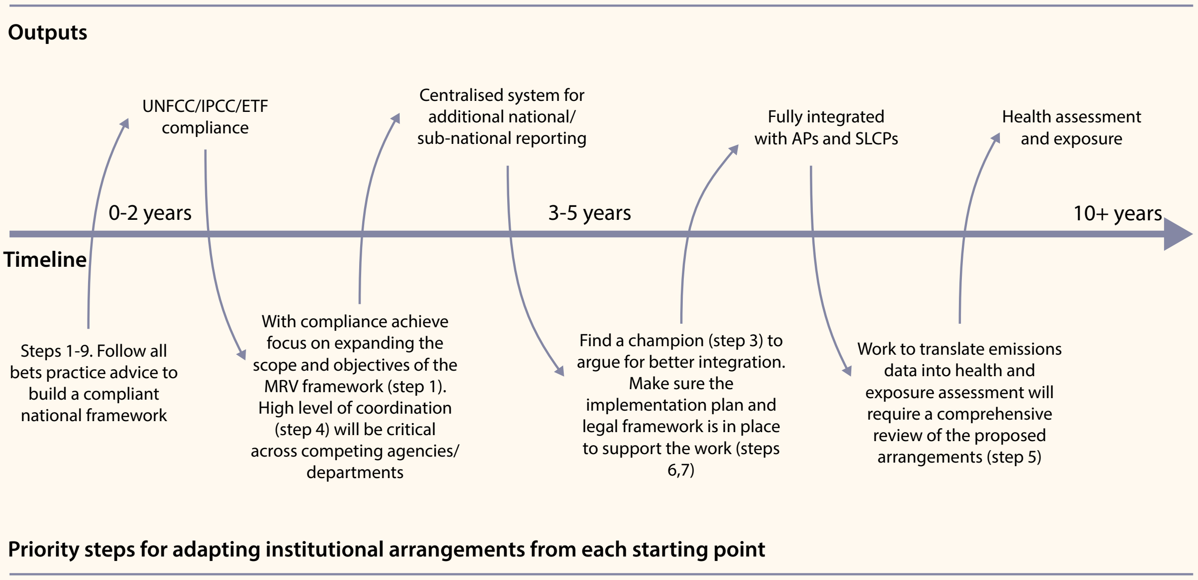
The development of an integrated air pollutant and GHG MRV system will enable a robust evidence basis of climate- or air quality-based action. By establishing data flows, organisational arrangements, and regular reporting requirements, users of the inventory and projections outputs can have confidence that they are using reliable, quality assured datasets. Policy makers, for example, can build economic cases for policies and measures, more accurately quantifying the benefit of particular mitigation actions on emissions of GHGs and air pollutants and the potential health impacts of both implementation of the action or the continued base case. Careful planning and continuous review and improvement enable this MRV system to adapt to emerging and shifting priorities, establishing institutional knowledge of how the system functions and how the system can be expanded or changed to implement particular improvements. Consideration of how the main climate and air quality related outputs of the enhanced MRV system in policy and measure evaluation and health impact assessments is provided in other sections of this guide.

Timelines for developing an integrated greenhouse gas, SLCP, and air pollutant MRV system

The above stepwise approach provides a basis for the development a national MRV framework for integrating GHG and air pollutant (including SLCPs). It is important to be realistic in estimating the timeframes needed to complete these steps in a manner that will be effective and long-lasting. Many countries will be at different starting points in terms of the existing national system. Depending on the starting point, it may be beneficial to break the steps down into smaller, more manageable tasks within a set time frame. For example, information already collected for the purposes of GHG inventory development and climate policy MRV frameworks can be utilised to provide a basic understanding of air pollution in a country and allow the identification of priority sectors for mitigation action and where data sources need to be improved to allow for more effective policy development. As methods refine, priorities may shift but it is important to begin and maintain progress with an attitude of continuous improvement, knowing that early action to mitigate sources of air pollution and greenhouse gases will have benefits to human health and the environment. Coordinators should keep the work output-oriented and prioritised, as well as monitoring the progression of tasks to confirm that key outputs are developed including ensuring that the MRV system is able to:

- Provide internationally (UNFCCC/IPCC/ETF) compliant GHG inventory and associated outputs.
- Consider air pollutants alongside GHGs and report their emissions at least to key stakeholders who develop policies or local air quality management plans.
- Provide policy makers and evaluators sufficient information on the potential impact of individual mitigation actions on GHG and air pollutant emissions and wider impacts on health, so that a broader consideration of environmental impacts can be adopted as standard in policy development.
- Centralise key inventory datasets for the efficient reporting of additional national/international reporting needs.
- Identify and prioritise improvements, including gaps or expansion requirements for expertise, data analysis, policy evaluation, and progress tracking.

These bullet points to some degree summarise and simplify the detailed information and recommendations provided throughout this guidance in **Sections 3, 4 and 5**. The following Figure 17 offers a suggested timeline that places the institutional steps required against the achieved reporting goals that can be achieved. Existing national systems from South Africa, Asia and the UK highlight real world examples that are at different stages on this timeline. For each starting point, the timeline could be used as a reference for defining the priority steps that are needed to achieve the next major output level.



Steps 1-9. Follow all bets practice advice to build a compliant national framework

With compliance achieve focus on expanding the scope and objectives of the MRV framework (step 1). High level of coordination (step 4) will be critical across competing agencies/ departments

Find a champion (step 3) to argue for better integration. Make sure the implementation plan and legal framework is in place to support the work (steps 6,7)

Work to translate emissions data into health and exposure assessment will require a comprehensive review of the proposed arrangements (step 5)

Figure 17: Overview of spectrum of progress on integration of air pollution and climate change.

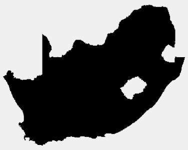
7

Case Studies

Case Study 1

SOUTH AFRICA

Photo by Zoë Reeve on Unsplash



Case Study 1

Considerations for integration of air pollution and climate change monitoring in South Africa

Authors:Tirusha Thambiran, Yerdashin Padayachi, Sarisha Perumal and Brian Mantlana (Council for Scientific and Industrial Research, South Africa)

Like many developing countries, South Africa has in its recent past seen increases in energy consumption, industrial activity and transport demand. The country's heavy reliance on coal and fossil fuels has contributed to air quality degradation. The legacy of poor planning practices of the Apartheid era has resulted in human settlements being built in close proximity to large point sources of emissions and thus increased health risks associated with air pollution exposure.

Over the past decades, South Africa has taken strides to address air quality and climate change issues through separate policies. In particular, this includes the development of South Africa's response to developing and implementing air quality and climate change legislation and policy, and progress on tracking the interventions made. However, increasingly, there have also been efforts to address both phenomena simultaneously. Whilst the country has yet to fully integrate SLCPs into its GHG reporting systems, the existing policies and MRV systems established position the country to advance its programme of integration and maximise opportunities for air quality and climate change co-benefits.

Air Quality and Climate Change Legislation

South Africa's initial and outdated Atmospheric Pollution Prevention Act (APPA) Number 45 of 1965 (focused on air pollution emitters) has been replaced by the National Environmental Management: Air Quality Act 39 of 2004. The National Framework for Air Quality Management (2008) and subsequent amendments, allowed for updating of the 2004 Air Quality Act by introducing international best practice in air quality management through a move to effects-based management supported by national ambient air quality standards. Additionally, under the National Framework, all local municipalities are required to develop air quality management plans (AQMPs).

The industrial sector was the initial sector for which supporting air quality legislation and regulations were put in place. Specifically, activities that release harmful emissions were categorised, emission standards were set along with processes to issue Atmospheric Emission Licenses (AELs). These regulations also included fines for exceeding emission levels and requirements for any upgrades and new developments to apply for an AEL as part of its Environmental Impact Assessment. Even though this legislation was recognized as being progressive, drawing on international best practice, it had challenges with respect to implementation, particularly in the context of competing priorities.

The Air Quality Framework (2008) also paved the way for amendments to the prevailing Air Quality Legislation such that it was aligned with the country's growing response to climate change. South Africa's response to climate change takes place in the context of the legacy of injustices and inequalities resulting from Apartheid rule. As such, the country's climate change response contributes to the national efforts of addressing poverty, inequality and unemployment (the 'triple challenge') while pursuing the SDGs.

In 2011 South Africa published its National Climate Change Response Policy White Paper which prompted the country's response to adapting to, and mitigating climate change. The initial focus of the climate change response was informed by the Long-Term Mitigation Scenarios which was followed by the research developed through the Long-Term Adaptation Scenarios. Action on the mitigation efforts needed were cemented through the country's first NDC, published in 2015 and revised in 2021.

South Africa also declared GHGs as priority air pollutants and industries are required to submit pollution prevention plans. This is significant as industries in the country are reliant on fossil fuels, and the GHG reduction measures that now need to be planned for may have significant co-benefits for improving air quality. Previously industries only controlled their air pollution emissions (primarily through end-of-pipe technologies) and reported this information on an annual basis to the government. With the introduction of GHG sectoral emission targets, carbon budgets and in response to the Carbon Tax, further work on integrating air pollution and GHG reporting to the national reporting systems has progressed. The country's Climate Change Bill was approved by cabinet in September 2021.

Climate Change and Air Quality Reporting Systems

Climate change and air quality related legislation have provided the regulatory framework for the development of air quality and climate change reporting guidelines and databases. The key databases of relevance to air quality management and climate change mitigation are described in more detail below.

Climate Change Reporting

SAGERs: The South African Greenhouse Gas Reporting Emissions System (SAGERS) is an online portal for the reporting by industries in the implementation of the National Greenhouse Gas Reporting Regulations (NGERS). The reporting platform is based on the 2006 IPCC reporting methodology. The portal is implemented and coordinated by the Department of Forestry, Fisheries and Environment (DFFE). The SAGERS serves as a data collection platform for activity data and emissions from industry by IPCC activities. Six climate pollutants are considered within the NGERs: Carbon dioxide (CO_2); Methane (CH_4); Nitrous oxide (N_2O); Sulphur hexafluoride (SF_6); Perfluorocarbons; (PFCs) and Hydro HFCs. The GHG national system builds from the ad-hoc GHG inventory processes started in 2008. Mandatory National Greenhouse Gas Emissions Reporting Regulations (Gazette No. 40054 of 2016) and National Atmospheric Emission Reporting Regulations (Gazette Number 38633 of 2015) have been published. These regulations provide the requirements on what should be reported and by whom.

National Climate Change Response Database: facilitates the monitoring and tracking of national, provincial and local responses to climate change. The National Climate Change Response Database (NCCRD) is intended as a resource to collect and track interventions on climate change (adaptation and mitigation) on past, current and future climate change response efforts (policies, plans, strategies, projects and research) across South Africa. This database supports the compilation of Biennial Update Reports to the UNFCCC, wherein the emission reductions from mitigation actions are estimated and reported.

National M&E system: The country has developed its Integrated National Climate Change Response Monitoring and Evaluation (M&E) System that seeks to integrate the network of databases maintained by different government departments and other institutions in the country. The web-based system serves as a means of tracking the flow of climate change data and information, climate finance and related communication. The outputs from the system are used to support reporting to the UNFCCC on progress made towards climate change goals (Figure 18).

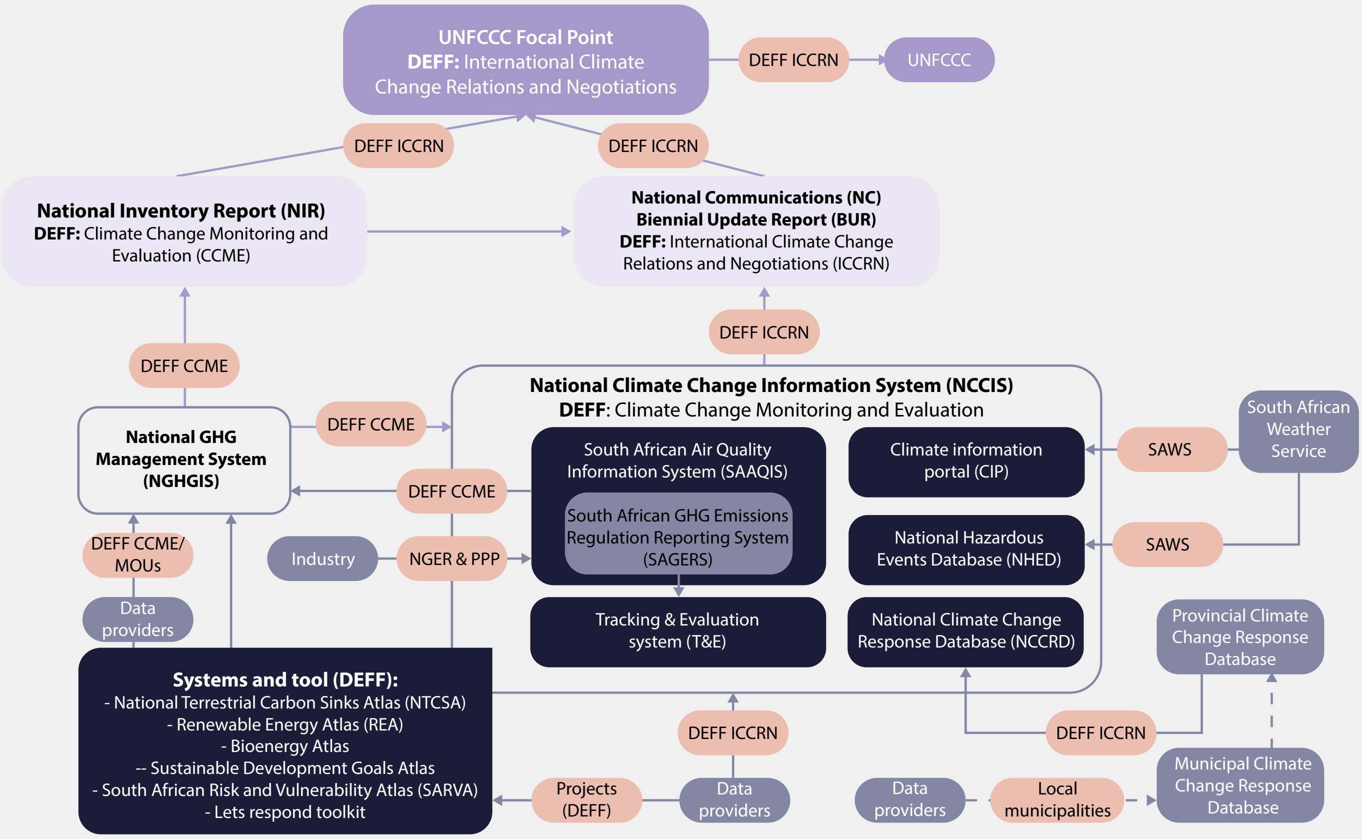


Figure 18: South Africa's integrated Climate Change Monitoring and Evaluation System (Source: DEFF, 2020).

Air Pollution Reporting

SAAQIS: The South African Air Quality Information System (SAAQIS) is a web based interactive air quality information system which seeks to provide the state of air quality information to citizens, and is a research portal for strengthening policy development related to air quality issues. All local municipalities report their air quality monitoring data to the SAAQIS which is managed by the South African Weather Services. The public are thus able to view the latest air quality monitoring data and request historic data on air pollutant concentration levels.

SAAELIP: The South African Atmospheric Emissions Licencing and Inventory Portal (SAAELIP) is an online portal for the management of Atmospheric Emission Licenses (AELs). SAAELIP comprises of two key components namely the National Atmospheric Emissions System (NAEIS) and the System for National Atmospheric Emission Licensing (SNAEL). The information from SAAELIP thus supports the estimation and compilation of atmospheric emissions inventories.

NAEIS: The National Atmospheric Emission Inventory System (NAEIS) is an online atmospheric emissions reporting system for operators to submit air quality emission inventories for their facilities. The purpose of NAEIS is to maintain a database containing information about significant sources of atmospheric emissions in South Africa. All activities requiring an AEL, activities declared as controlled emitters, and facilities generating criteria pollutants report on their air pollution emissions. Annual reports will be published by DFFE by the end of each year which reports the total emissions of each criteria pollutant per sector. Detailed emission data at facility level will be made available at cost to scientists and consultants (DFFE, 2021).

SNAEL: The System for National Atmospheric Emission Licensing (SNAEL) provides licensing authorities with the ability to: i) Process and issue (provisional) AEL applications online, ii) Monitor the status of online licence applications, iii) Process licence fees and record payments for each application; and iv) Manage online compliance reporting for licence holders.

Through the NAEIS and SNAEL systems the country has been able to make progress with the development of its national industrial emissions inventory, on an annual basis. However, data for other key sources such as biomass burning, road transportation, domestic burning, waste management and wind-blown dust are not well captured at a national level. Emission inventories at a local level experience similar constraints and are typically only updated when Air Quality Management Plan (AQMPs) are reviewed. The level at which all sources are captured within a local level inventory varies, depending on data availability and resources to conduct additional studies to supplement the industrial component. As a result of several municipal and provincial level projects, emissions inventories have been compiled for non-industrial sources. However, many of these inventories are severely flawed due to a lack of consistency and uniformity in how they were compiled and a lack of proper QA/QC protocols. Air pollution data is relatively incoherent locally, with data repositories that are not easily accessible.

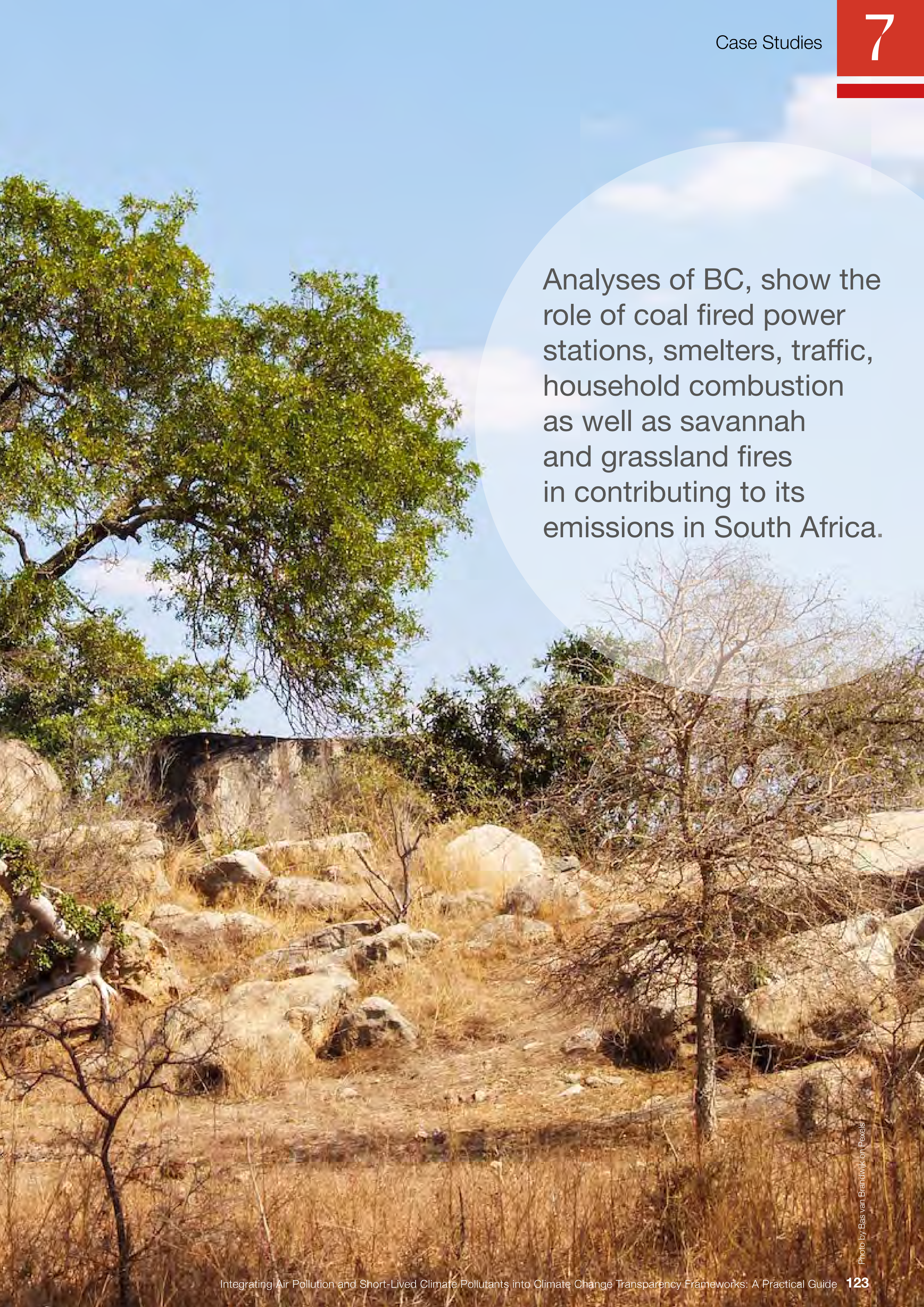
Opportunities for achieving integrated action on air pollution and climate change in South Africa

Therevhave been notable successes in reducing levels of sulphur dioxide (SO_2) emissions in some parts of the country primarily through the introduction of end-of-pipe technologies installed for compliance with AELs. The key metropolitan municipalities have developed air quality management plans and key air pollution hot spots have been declared priority air quality areas with focused air quality management interventions. PM remains the greatest national cause for concern for poor air quality. Analyses of BC, show the role of coal fired power stations, smelters, traffic, household combustion as well as savannah and grassland fires in contributing to its emissions in South Africa.

South Africa's NDC, by virtue of the types of interventions (renewable energy and energy efficiency) needed to reach the climate change mitigation goals are likely to result in reduced air pollution and improved air quality in the key air pollution hot-spots in the country (particularly for those communities in close proximity to coal-fired power stations).

South Africa recently struck an historic R130-billion (7.72-billion USD) deal at COP26 with the UK, US, France and Germany to accelerate a just transition away from coal. This makes the need for a scientific evidence base for the integration of SCLPs even more pressing. There is some ambiguity as to what coal will be replaced with and understanding the role of SLCPs could make an impact on policy decisions. There are a range of strategies and actions that target major sources of SLCPs and improve local air pollution that global studies have explored. However, currently, the potential role of SLCPs in South Africa's climate change ambitions is not well understood, with limited studies being conducted to date, confined to selected case study areas.

The purpose of an integrated approach would be to promote the growth and application of policies like the NDC, AQMPs and Climate Action Plans that simultaneously target air pollution and climate change, with a view to optimizing interventions with co-benefits. This can be promoted through integration of GHG and air pollution emission inventories; evaluation of the impact of climate change mitigation on air quality and health and the impacts of air quality management on GHGs and SLCPs.



Analyses of BC, show the role of coal fired power stations, smelters, traffic, household combustion as well as savannah and grassland fires in contributing to its emissions in South Africa.

Photo by Bas van Brandwijk on Pexels

Integrating air pollution and climate change reporting

Some efforts have been made in South Africa to integrate assessment of air pollutants, SLCPs and GHGs. Integrated assessment models such as Stockholm Environment Institutes LEAP-IBC and IIASA's GAINS model have been successfully used to compare air quality and climate benefits accrued from different policy scenarios for cities in Gauteng. These studies often propose quantifiable emission reduction targets, like the recent World Bank Funded AQMP for the cities of Johannesburg-Ekurhuleni-Tshwane (JET). In addition to air pollutants, with a focus on PM2.5, the study also considered changes in the emission of OC, BC and CH_4, in response to different policy levers. The study used the GAINS model, which explores cost-effective emission control strategies that simultaneously tackle local air quality and GHG emissions to maximize benefits at all scales. Similar types of studies across other areas of the country are also needed.

At the national scale, South Africa's National Climate Change Response White Paper provides the national and international political and development context against which the MRV system has been developed. Similarly, the National Framework for Air Quality Management of 2008 (updated in 2017) provides the overarching guidance for air quality planning and policies in the country. The development of both the White Paper and the National Framework was undertaken through a consultative process, that engaged leading scientists, policy-makers and practitioners within the country, regionally and internationally. This also involved numerous interactions with broader stakeholders in society through workshops and the commissioning of research studies. This process of engagement has been key to scoping out the needs for further research, policies, plans and legislation needed. These processes also contributed to understanding the nature of the institutional infrastructure, resources and capacities that were needed to effectively implement the M&E system at a national level of government and the structures that were needed.

Currently, due to the different level of detail on reporting in different air pollutant-emitting source sectors, the considerations in integrating climate change and air pollution reporting differ for industry/energy and other sources. South Africa has made significant progress in developing legislation and reporting systems to tackle atmospheric emissions, primarily focusing on the large point sources (energy and industrial sectors).

There are challenges that remain, particularly from an air quality perspective:

- Low levels of compliance and enforcement of regulations.
- Local government has limited capacity in terms of delivery in general.
- Restricted access to detailed activity data for industrial emissions.
- Lack of data on non-industrial emissions
- Low recovery data from air quality monitoring stations.
- Issues of poor transparency, with the public at large lacking access to emissions data via databases such as the SAAQIS and the NAEIS.

Efforts that are put in place to integrate SLCPs and GHGs should thus also look at how these synergies could help resolve or reduce some of the challenges currently experienced, through allowing for the overall M&E system to become more effective and cost-effective. The key considerations for the integration for different industrial and non-industrial sectors include:

Industry

There are already reporting systems in place as well as the guidelines on reporting for the industrial and energy sectors. These aspects of the MRV systems and databases are therefore more advanced and have potential for a more integrated approach. The primary purpose of climate change mitigation monitoring and reporting at facility level in South Africa is to centralise the

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collation of GHG emissions data which can be aggregated and applied for international reporting requirements to the UNFCCC. It does not serve as an instrument to enforce emission reductions based on energy usage or emission thresholds that trigger reporting for priority air pollutants. However, carbon taxes (Carbon Tax Act No. 15 of 2019) are levied onto regulated activities based on emission thresholds, and there are tax-free allowances for implemented emission reduction activities which lower the tax obligations of the polluter.

The submitted emission reports (Pollution Prevention Plans – PPPs) must meet the quality assurance principles of transparency, completeness, accuracy, comparability, consistency and adherence to the Methodological Guidelines for Quantification of GHG emissions. The latest version of the guidelines (DEFF, 2021) follows the structure of the IPCC (2006) reporting guidelines for calculation of emission sources and sinks. Six climate pollutants are considered within the NGERs: CO_2, CH_4, Nitrous N_2O, SF_6, PFCs and HFCs. According to the structure of the 2019 refinement to the IPCC reporting guidelines, there is a need to update the methodological guidelines. There is also potential for a wider scope of additional gas species to be considered including NO_x, CO, NMVOC and SO_2 (Sanz Sánchez et al., 2006) for emissions accounting. It is noted that BC, Ozone (O_3), cooling aerosol species and aerosol precursors which are amongst the primary SLCPs are excluded from the list of additional gases in the IPCC guidelines.

BC is mentioned as a possible future pollutant of concern in the update of South Africa's National Framework for Air Quality Management (DEA, 2018) though is presently not a priority air pollutant.

In the NAEIS, emissions of a range of pollutants for each sector are reported, including GHGs. Levels of O_3, PM_{10} and $PM_{2.5}$, and aerosol precursors which are reported in the NAEIS, are important for climate change and should feature in an integrated system.

There is also the issue of transparency. It is currently very difficult to access and share detailed activity data on industrial emissions for studies on air pollution and climate change. An integrated system would be made possible by overlapping data requirements. However, to be practically implemented, an integrated SLCP and GHG inventory, and the existing MRV systems, will require additional sources of data and emissions factors, as well as the systems and platforms required to capture the additional information needed and related systems architecture. This can be linked to the current data flows and responsibilities of data custodians to support improved integration of air quality and GHG information.

The challenges for an integrated system does not end with the tracking and collation of emission inventories. Contributions from major SLCPs to emission reductions should also be accounted for. Current methodological guidelines for the calculation of emission reductions are provided by the global carbon credit standards mentioned in the carbon offset regulations (National Treasury, 2019) including the Clean Development Mechanism, Gold Standard and Certification Body and Verified Carbon Standard. Through the Partnership for Market Readiness project of the World Bank, a framework to guide the development of local standards and methodologies for calculating and reporting emission reductions were developed which will be published by the Department of Mineral Resources and Energy (National Treasury, 2021). The inclusion of SLCPs into this framework should be explored.

Non-industrial source sectors

Non-industrial related emissions in the Energy, Waste and AFOLU categories have not been given as much attention as industrial sources. These non-industrial activities are important sources of SLCPs, particularly from waste management and agriculture (Lund et al. 2020). City level studies in the country have revealed that even when industrial and energy related emissions are reduced, non-industrial emissions still play an important role for air quality and health.

In the case of non-industrial emission inventories, these inventories are often more ad-hoc and irregularly compiled. National government through the DFFE has proposed a new approach to advance the development of a new National Emissions Inventory (NEI) system that will more holistically include non-industrial sources of emissions. To this end, the South African government is currently commissioning a study to investigate how information/data from multiple-systems can be integrated into a coherent one-stop national system, such that non-industrial emission sources are collected in a more routine way, with quality control and assurance methods in place. Whilst it is envisaged that the non-industrial emissions inventories will include both long-lived GHGs and air pollutants, it will be imperative that it should, at the outset, also consider the links between SLCPS and GHGs.

Regulatory and institutional considerations to operationalise an integrated reporting approach

From the country's experience of setting up the current integrated M&E system there is a need to outline a framework for engagement with different role-players to map, understand and identify existing MRV practices, data flows and capacity needs to integrate SLCPs and GHGs, such that the information contained in the atmospheric emissions databases link to the GHG databases (Figure 19 on the next page). For this to happen there needs to be a supporting policy or regulatory environment under the Air Quality Act that calls for such integration to occur, and thus prompts this action to occur. Furthermore, existing regulations may need to be amended to fill gaps that may exist in current reporting structures (for example differences between thresholds for CO_2 emissions and requirements for industries as scheduled air pollution related processes). There will be a further need to develop data reporting and management guidance. Capacity building and training on these guidance documents will be required in order to equip all role players across public and private entities with understanding of the methods for accounting for SLCPs and reporting requirements.

The scale at which climate change mitigation targets and air quality goals are set also varies, with the NDC providing a national goal and municipalities delegated the responsibility of developing air quality targets within AQMPs. Policy guidance and supporting regulatory systems will be needed to ensure that there is vertical integration between the overarching climate change goals and the mitigation potential within city level AQMPs, including alignment of periods of implementation and targets for emission reductions. Regulations that define the roles and responsibilities of different government departments, private entities and within different spheres of government will also need to be developed.

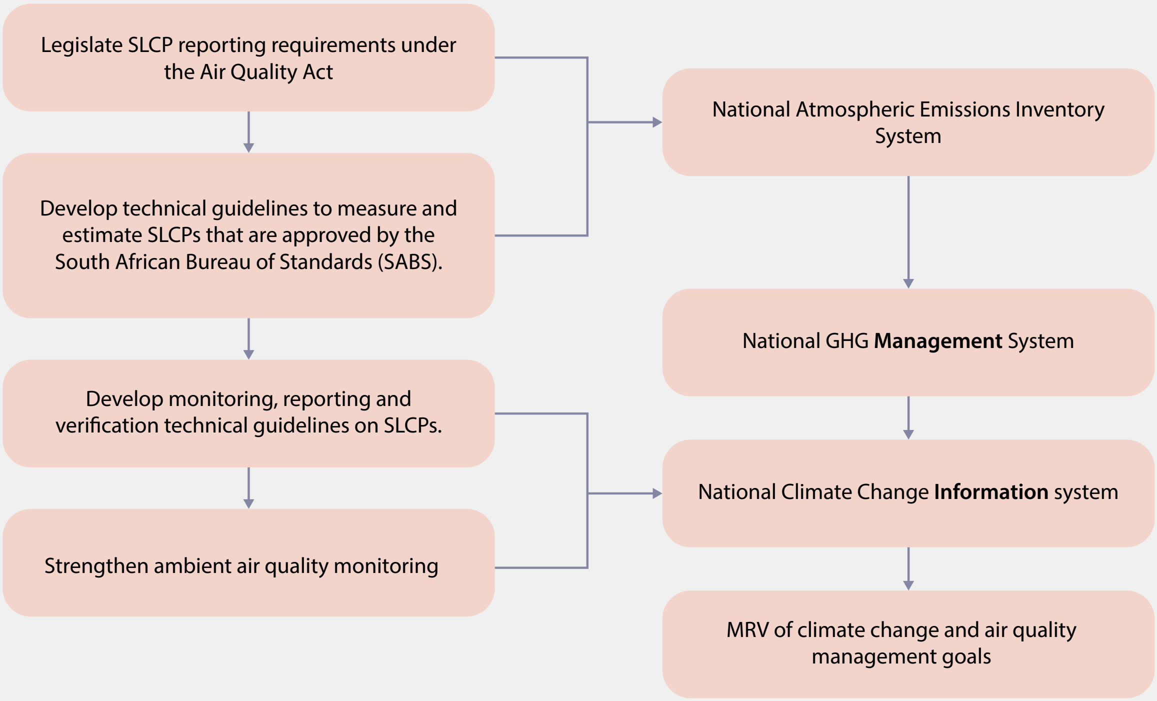

Figure 19: Incorporating SLCPs in the national M&E system.

Utilisation of information provided in integrated monitoring system

The integration of SLCPs and GHGs may offer a more streamlined process that could contribute to make MRV processes more efficient and thus result in better utilization of available resources and capacity. The integrated information will support tracking progress towards climate and air quality goals, as well as leveraging opportunities for additional support and action, such that the integrated data can be used across local, national and international reporting, for example in:

- International climate change reports submitted to the UNFCCC
- Annual Climate Change Reports produced by DFFE
- Annual National Assessment of the State of Air Quality
- Reviews and updates on the NDC and AQMPs
- SDG reporting
- Data and information for the SAAQIS
- Reviews and updates of local AQMPs
- Providing a more holistic view of projects with quantified co-benefits within the climate change response database.

The integrated system will further support efforts to tag climate-related expenditure in the government budget system by providing a better reflection of investments, particularly those with quantified and verified co-benefits.

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Case Study 2

PHILIPPINES

Case Study 2

Clean Air Asia - City Scale Action on air pollution and climate change (Philippines)

Authors: Precious Benjamin and Dang Espita-Casanova (Clean Air Asia, Philippines)

This guide has primarily focused on the integration of air pollution and climate change MRV at the national scale, due to the international processes that require countries to submit national GHG emission inventories into which air pollutants and SLCPs could be integrated. The national scale is also where international climate change commitments, through NDCs, are made and communicated. However, there is also a large opportunity at the sub-national scale to integrate planning, decision making and monitoring of climate change mitigation and air pollution. Cities globally are responsible for the majority of GHG emissions and suffer the largest health burdens from exposure to air pollutants. Many of the policies and measures that achieve the largest simultaneous benefits for air pollution and climate change are implemented in cities (e.g. electric mobility). This case study presents an example of how the integration of air pollution and climate change planning can be integrated at the city-level for one city, from technical and institutional perspectives, and the advantages and challenges in achieving this.

City Profile

Santa Rosa, Philippines, is a city of 300,000 people, located around 40 kilometers south of Metro Manila (Santa Rosa City Government, 2022; Philippine Statistics Authority, n.d.). It used to be mainly an agricultural area but has experienced rapid economic growth, and has seven special economic and industrial zones. These economic zones house, among others, multi-national automotive companies, and manufacturing operations of food and beverage companies (Santa Rosa Socio-Economic and Physical Profile, 2018). It is also a hub for outsourced business processes such as customer service, software development, and transcription. In addition to commercial developments, the city's population is also increasing due to migration from Metro Manila. These, together with the fact that Santa Rosa serves as a gateway to more southern destinations in the region, intensify transport activity within the city.

Santa Rosa's commitment to strengthening its air quality management capacity and addressing emission sources started with its participation in Clean Air Asia's Cities for Clean Air initiative from 2016 to 2018. As one of the three pilot cities, Santa Rosa implemented a set of actions on engaging stakeholders, consolidating and communicating air quality information, and taking measures to reduce emissions. After the conclusion of the pilot phase, the city through the City Environment and Natural Resources Office (CENRO) expressed a desire for a roadmap to continue addressing air pollution through the development of a clean air action plan. Moreover, the plan was envisioned to be consistent with the city's various climate change mitigation programs and activities. This case study documents the city's journey towards integrated air quality and climate action.

Integrated air quality and climate action planning in Santa Rosa City, Philippines

Clean air action planning in Santa Rosa provided an evidence-based and stakeholder-led approach to identifying pollution control measures that are most appropriate and feasible for addressing emission sources in a city. Key tools in the development of a clean air action plan include air quality monitoring (providing the status of air quality in the city), an emissions inventory (to identify pollution sources and their emission contributions, and health impact assessments (to understand the magnitude of air pollution impacts. The development of these tools can then be utilised by stakeholders in discussions and prioritisation of the pollution control measures.

These tools can also be integrated with climate change mitigation planning. In particular, and as outlined in **Section 4**, there is substantial overlap in the development of air pollution and GHG emission inventories. In Santa Rosa, the process for the development of the clean air action plan, and climate change action plan followed the same model. Specifically, an integrated emission inventory was developed and used as the basis for the selection and priority of the suite of control measures to reduce air pollution in the city and reduce its contribution to climate change.

Integrated emissions inventory

In 2020, the Santa Rosa City Government, together with Clean Air Asia and the University of the Philippines National Centre for Transportation Studies (NCTS) developed an integrated emissions inventory as part of the city's efforts in increasing its air quality management capacity and collecting baseline data for its clean air and climate action plan.

The Santa Rosa CENRO, as the office tasked with environmental management, served as the lead agency for the inventory. Moreover, in recognition of air pollution as a multi-sectoral issue that needs to be addressed by different city departments aside from the environment office, CENRO requested that an Executive (or Mayoral) Order be signed forming the Santa Rosa Clean Air Core Team for the Clean Air Program. The Core Team is an inter-agency group composed of representatives from the environment, planning, health, traffic management, and others whose functions are related to, or effect the management of emission sources within the city. During the development of the inventory, a two-day workshop on the integration of SLCPs into city plans and policies provided a platform to discuss the emissions inventory as a means for integrated planning on air quality and climate change and mechanisms for institutionalizing the inventory within the CENRO work and the city's planning system.

The emissions inventory project comprised the following components:

- Development of the inventory (data mapping, data collection, quality control and quality assurance, emissions estimation, spatial mapping of emissions).
- Spreadsheets and report preparation (development of spreadsheets for the activity data and emissions estimation, which can be updated during future inventories; documentation of data utilized, methods and results).
- Capacity building of the Santa Rosa City Government through training workshops and hands-on learning.

From the outset, the inventory was also designed to be an integrated inventory, covering traditional air pollutants, namely particulate matter PM_{10} and $PM_{2.5}$, carbon monoxide, sulfur dioxide, nitrogen dioxide, and NMVOCs, GHGs such as carbon dioxide, nitrous oxide, methane, and BC. The inventory covered all major source sectors, including point sources (industries and electricity generation), area sources (household and commercial fuel combustion, agricultural residue burning, and other agricultural sources), mobile sources (road and non-road transport).

Consistent with **Section 4** of this guide, and international emission inventory guidance, emissions were estimated by multiplying activity data by emission factors. The activity data required for each source was based on what is prescribed by the Atmospheric Brown Clouds (ABC) Emissions Inventory Manual as well as the activity data used in the Marikina City, Philippines Emissions Inventory conducted by Clean Air Asia in 2018. A corresponding data collection method was selected by Clean Air Asia, NCTS and the Santa Rosa EI Core Team for each source. The ABC Emissions Inventory

Table 7: Activity data required for each pollution source with corresponding data gathering and sampling method.

Major category of pollution source	Existing pollution sources in Santa Rosa City	Annual activity data required (2019)	Tier	Data gathering and sampling method
Area Source	Residential activities	• Fuel type used and amount consumed • Amount of waste produced • Amount of waste burned • Amount of household and personal product consumed	For fuel combustion: Tier 1 with default emission factors Non-methane volatile organic carbons are not included in IPCC Guidelines	House-to-house surveys Out of 18 barangays (villages) in the city, eight were surveyed with 15% of households for each barangay interviewed. Data from the surveyed barangays were used to estimate the emissions for the non-surveyed barangays.
	Commercial activities			Commercial establishment surveys 'Establishments of concern,' or establishments with activities resulting to non-negligible emissions for the inventory were identified, out of which a sample of commercial establishments were surveyed.
	Crop residue open burning	• Land area of cultivated and harvested area; Annual yield of crops (default percentage of biomass burned can be used) • Amount of biomass burned	Fuel combustion: Tier 1 Note: Crop burning is not allowed in the city, with no data on incidences (if any), so emissions from crop burning were not calculated.	Utilized data from City Agricultural Office.
	Agricultural sector activities such as fertilizer use and animal manure management	Head count of animals	Tier 1	Utilized data from City Veterinary Office.
		Amount of fertilizer used	Tier 1	

Table 7: Activity data required for each pollution source with corresponding data gathering and sampling method cont...

Major category of pollution source	Existing pollution sources in Santa Rosa City	Annual activity data required (2019)	Tier	Data gathering and sampling method
Point Source	Heavy manufacturing facilities	• Fuel type used and amount consumed • Combustion technology • Pollution control device installed	Tier 1 fuel-specific emission factors	Utilized activity data for combustion extracted from Self-Monitoring Reports submitted by the facilities to the regional environmental management bureau Emissions brought about by waste generation, the use of products with solvents, etc. were not included as these were not provided in the self-monitoring reports.
Mobile Source	On-road vehicles	Classified vehicle volume count for selected roads: • Vehicle type • Vehicle age • Vehicle kilometers travelled	Tier 2 involving disaggregation of the vehicle fleet by vehicle type; percentage of vehicles of each type within different age groups and conforming to different vehicle emission standards; average distance travelled by vehicle type per year; average fuel efficiency of vehicles of each type (factored in as part of vehicle age)	Classified vehicle volume count survey was performed in main, representative intersections within the city to determine general vehicle composition. Travel time and delay studies in main roads were also performed to determine average vehicle speed. Public vehicle composition was based on the database provided by the Land Transportation Franchising and Regulatory Board Region IV-A as well as by the City Engineer's Office.

Manual and Spreadsheet were used as these were developed based on IPCC guidelines, among others, allowing more flexibility in using the activity data and emission estimates for the GHG reporting of Santa Rosa City in national and international platforms. Table 7 summarizes the activity data utilized and data gathering method employed for each type of pollution source.

Data clean-up and quality control/quality assurance methods were employed prior to emissions estimation. Default emission factors for Point, Area and Mobile Sources were taken from the ABC Emissions Inventory Spreadsheet. There were also emission factors from local studies used for some pollutants under mobile sources.

The main findings of the emissions inventory were that mobile sources are the dominant emission sources for most of the pollutants including PM_{10}, $PM_{2.5}$, carbon monoxide, nitrogen oxide, NMVOCs, nitrous oxide, methane, and black carbon. Table 8 summarizes the dominant pollution source for each pollutant while Figure 20 on the following page shows the contribution of the main source categories. The emissions inventory was useful for identifying the pollution sources that exist within the city, the city agencies tasked to manage or oversee these sources and activities relevant to them, as well as the sources that need to be prioritized due to their dominant contribution to emissions.

Table 8: Summary of dominant pollution sources for each pollutant.

PM_{10}	Mobile - Motorcycles
$PM_{2.5}$	Point (Barangay Balibago) and Mobile – Tricycle
carbon monoxide	Mobile – Cars
sulfur dioxide	Point – Barangays Don Jose and Pulong Santa Cruz
nitrogen oxides	Mobile – Cars
NMVOC	Mobile – Motorcycles
carbon dioxide	Point – Barangay Don Jose
nitrous oxide	Mobile – Jeepneys
methane	Mobile – Cars and Area - Residential cooking
black carbon	Mobile – Jeepneys

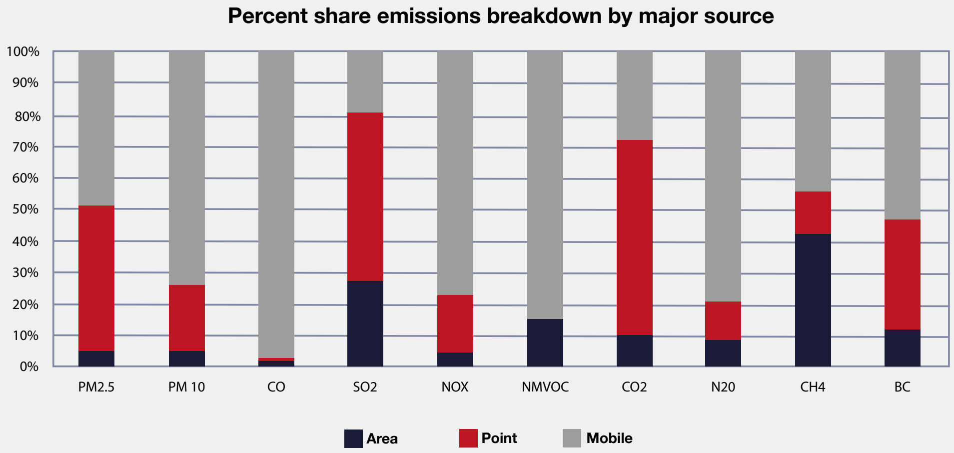


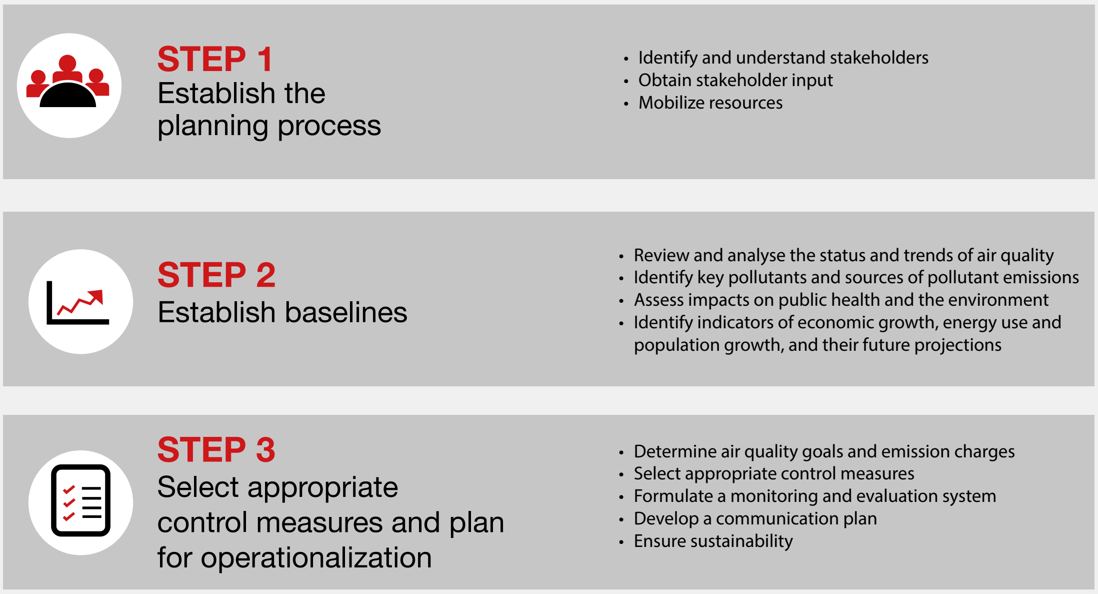
Figure 20: Percent share emission breakdown by major source Source: Clean Air Asia, 2021.

Development of Clean Air and Climate Action Plan including mechanisms for integration (CACAP)

In the Philippines, the Local Government Code of 1991 devolved a number of key functions to local government units (i.e. cities and municipalities). These include, among others, the power to perform local planning, budgeting, implementation, and monitoring of said plans (HLURB, 2013). The Comprehensive Land Use Plan serves as the long-term plan for the physical development of the respective territories of local governments, legally enforceable through zoning ordinances (DILG-BLGD, 2008). The Comprehensive Development Plan, on the other hand, is a multi-year, multi-sectoral development plan that covers the socio-economic side of planning and lists the programs, projects, and activities that the city will undertake to cover its development targets. The rationalization of the local planning system in the Philippines aims to simplify the local planning system and outline the process of integrating sectoral plans into these.

The Philippine Clean Air Act of 1991 defines an airshed-based air quality management system for the Philippines. This means that Clean Air Action Plans are required at the airshed-level (i.e. the area of the atmosphere above a city or region that emissions from the city or region experience the same dispersal characteristics) and only encouraged at the local government level to be aligned with the respective airshed plan. However, the multi-sectoral nature of the Comprehensive Land Use Plan and Comprehensive Development Plan as well as the climate change mitigation component of another required city plan, the Local Climate Change Action Plan, create a mechanism for integrating clean air and climate change action plans into nationally-mandated local government plans.

The framework shown in Figure 21 for developing a clean air action plan was utilized for Santa Rosa. The establishment of the planning process and mapping of stakeholders commenced even before the start of the emissions inventory project, when the city established the Santa Rosa Core Team for the Clean Air Program in 2018, with CENRO as the lead agency for the city’s air quality efforts. The emissions inventory was used as the baseline in terms of understanding the pollution sources in the city and their respective emissions contribution. As it was not covered by the resources for the development of the plan, it is recommended that the latter be updated with available air quality monitoring and health data to provide a more holistic picture on air quality levels and health impacts of air pollution in the city, respectively.



STEP 1
Establish the planning process

- Identify and understand stakeholders
- Obtain stakeholder input
- Mobilize resources

STEP 2
Establish baselines

- Review and analyse the status and trends of air quality
- Identify key pollutants and sources of pollutant emissions
- Assess impacts on public health and the environment
- Identify indicators of economic growth, energy use and population growth, and their future projections

STEP 3
Select appropriate control measures and plan for operationalization

- Determine air quality goals and emission charges
- Select appropriate control measures
- Formulate a monitoring and evaluation system
- Develop a communication plan
- Ensure sustainability

Figure 21: Recommended Clean Air Action Planning Process Source: UNEP and Clean Air Asia, 2019.

Step 3 of the process was the selection of appropriate control measures. Step 2 of the plan highlighted key sectors as making the largest contribution to air pollutant (and SLCP and GHG emissions), which focussed on where control measures needed to be implemented to improve air quality and mitigate climate change. A suite of clean air and climate measures were put forward to the City Government of Santa Rosa based on the 25 top Clean Air Measures presented in the ‘Air Pollution in Asia and the Pacific: Science-Based Solutions’ report on integrated air pollution and climate change action in Asia. Measures which complied with the following two criteria were then shortlisted and included in Santa Rosa City’s Clean Air and Climate Action Plan: (a) the measure should address a relevant emission source/s within the city, and (b) implementation of the measure is within the authority of the city government.

The following measures were included in the plan:

Control Measures for Area Sources (Residential, Commercial, Waste, Agricultural)

- Promotion of clean cooking for residential and commercial establishments.
- Promotion of the use of renewable energy sources.
- Promotion of energy conservation and efficiency in residential and commercial establishments.
- Strengthening solid waste management and enforcement of ban on open waste burning.
- Collaboration with farmers for better livestock manure management.
- Control Measures for Mobile Sources.
- Promotion of vehicle Inspection and maintenance.
- Shift to and/or increasing the use of electric vehicles.
- Performing transport management, as a first step through the development of a local public transport route plan.
- Promotion of non-motorized modes of transport.
- Adopting an integrated land use and transport planning approach in key plans such as the Comprehensive Land Use Plans and sectoral plans.

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Under the Philippine Clean Air Act of 1999, management of Point Sources falls under the authority of the regional environmental agency. Thus, measures such as ensuring compliance to emission standards or uptake of pollution control technologies were not included in the plan. However regular coordination was noted to exist between the said regional environmental agency and CENRO which resulted in the former's support of the city's emissions inventory. This regular coordination is expected to continue in the management of Point Sources, for instance by the city government reporting facilities which may require close monitoring by the regional agency. The control measures were discussed with the Clean Air Core Team in terms of feasibility and alignment with the city's priorities prior to their final inclusion in the plan. Aside from outlining general measures, mechanisms for implementation based on existing national policies and programs as well as ways for operationalizing them based on what has been done by Asian cities, written as case studies, were set forth in the plan to serve as guide for the city to carry them out.

Further opportunities for integrated air quality and climate action in Santa Rosa City

To further the integration of air quality and climate action following the development of the integrated emissions inventory and the clean air action and climate action plans, five key actions were identified that align with the information included in this guide were recommended for the city during initial stakeholder discussions, as described below:

- Application of the emissions inventory and the city's previous greenhouse gas inventory data for monitoring and evaluation of the clean air measures
- Quantification of air quality and climate co-benefits from selected pollution control measures
- Inter-agency coordination and collaboration on air quality and climate change mitigation
- Institutionalization of emissions inventory data collection and monitoring under clean air action planning and local climate change action planning
- Integration of short-lived climate pollutants into the city's database

Action 1

Application of the emissions inventory and the city's previous GHG inventory data for monitoring and evaluation of the clean air measures

To initiate this practice, activity data and emission estimates from the integrated inventory or other sources were recommended to be used as baseline data and performance indicators for the monitoring and evaluation of relevant clean air measures. The indicators can further be expanded by the Clean Air Core Team for the other measures when it sets up the monitoring and evaluation framework of the clean air and climate action plan. Table 9 includes the key monitoring indicators suggested to assess the implementation of the clean air plan. These can also serve as more detailed indicators that can be adopted when the city updates its Comprehensive Land Use Plan and other key plans. Under the Comprehensive Land Use Plan for 2018-2026, the success indicators or targets for air quality-related projects and activities were limited to the annual number of trainings, seminars and workshops on environmental management and the level of air quality monitored within the city. For the second indicator, however, it should be noted that monitoring is currently being performed by the regional environmental agency in one location within the city as the city government does not have its own monitoring equipment.

Table 9: Recommended baseline data and/or performance indicators for selected clean air and climate measures.

Clean Air Measure			Baseline data / Performance indicators					
			Emissions			**Activity Data**		
Clean cooking and heating	Use of cleaner fuels – electricity, natural gas, LPG.	None yet	Fuel type	PM10	PM2.5	Fuel used (Tonnes/yr)	No. of households using the fuel	Total households surveyed
			LPG	2.80	2.80	10,756.94	5435	6151
			Charcoal	2.83	2.40	726.70	200	
			Wood	1.17	0.99	234.02	91	
			Butane	0.0016	0.0016	6.08	60	
			Kerosene	0.01	0.00	0.00	15	
Solid waste management	Continued improvement of a centralized waste collection system with separation at source and proper disposal/treatment of residual waste.	Updating of the City Solid Waste Management Plan and its implementation	From 2019 integrated emissions inventory: CH4: 4.26 tons/year Waste generated: 102,504 tonnes/year					
Renewables for power generation	Use of incentives to foster extended use of wind, solar and hydro power for electricity generation and phase out the least efficient plants	Use of renewable energy	Baseline indicators • Number of establishments/facilities/households that use renewable energy. • Percentage of average electricity consumption from renewable energy sources vs from the main grid for categorized establishments/facilities/households. • Total no. of solar power streetlights installed in the city. • Energy consumption of ordinary streetlights vs. solar power streetlights. From 2012 Greenhouse Gas Inventory Report for the City of Santa Rosa on emissions from electric usage of city streetlights. • tCO2eq: 1,608 • kWh: 2,823,798 • Source: Regional electric distribution company					
Electric vehicle use	Promote the use of electric vehicles	Use of electric vehicles for government vehicles	Baseline indicators • Total number of electric vehicles vs regular vehicles per city department. • Average vehicle kilometers travelled of electric vehicles vs regular vehicles per city department. • Average energy consumption of electric vehicles vs regular vehicles per city department.					

Action 2

Quantification of air quality and climate co-benefits from selected pollution control measures

Based on the emissions inventory performed for the city, measures addressing mobile sources or the transport sector were identified as priorities due to their dominance in terms of emissions contributions for majority of the pollutants. The project on SLCP integration supported by the UN Environment Programme / Climate and Clean Air Coalition (UNEP/CCAC) created an opportunity for the Institute for Global Environmental Strategies to apply the Transport Emissions Evaluation Models for Projects" (TEEMP) Model – City Version for specific transport measures selected by the Santa Rosa City Clean Air Core Team. The TEEMP application strongly supports the integrated approach by demonstrating air pollution and climate benefits from the implementation of transport measures.

The transport measures applied in TEEMP were as follows:

- Enforcement of the vehicle inspection and maintenance system through roadside vehicle testing
- Promotion of non-motorized transportation, specifically the development of bikeways to promote biking as a means of transportation

The application resulted in estimation of emissions for CO_2, PM_{10}, and NO_X for three scenarios:

- Business-as-usual or no intervention
- Reduction overall vehicle emissions by 10% through vehicle inspection and maintenance enforcement
- Shift in use of passenger cars for 20% of vehicle kilometers traveled to biking
- Combined reduction in overall vehicle emissions (10%) and shift from passenger car use to biking (20%)

The results show that adopting the maximum targets on vehicle inspection and maintenance as well as the promotion of non-motorized transport having a joint implementation of the measures on would best benefit the city. Building on the TEEMP application, a costing of the measures and economic quantification of the benefits from the emission reduction would be most helpful to inform decision-making and the allocation of resources.

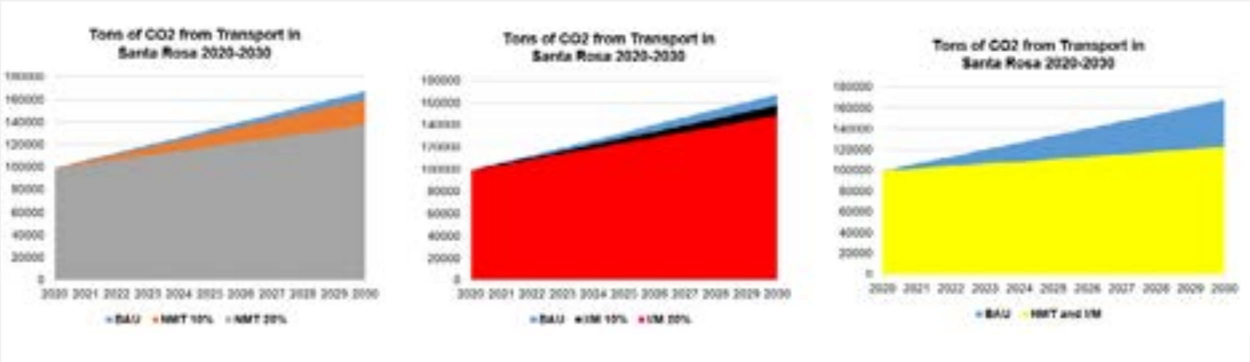

Figure 22: Tons of CO_2 emissions from transportation scenarios in Santa Rosa City for 2020-2030.

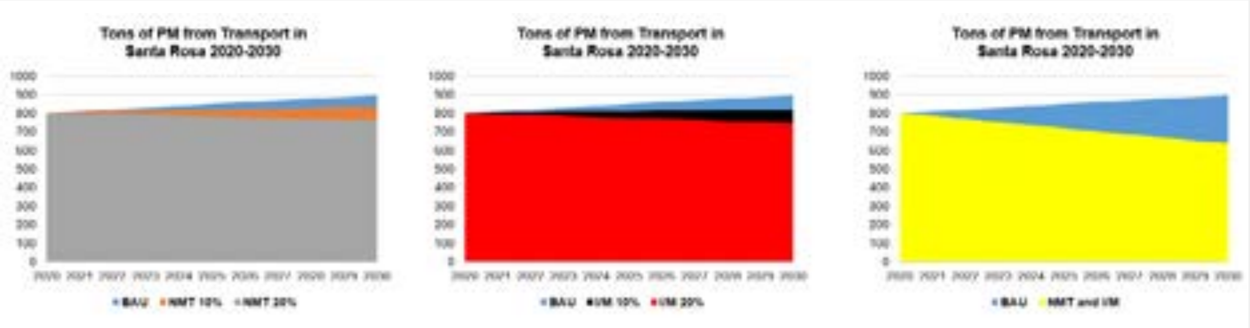

Figure 23: Tons of PM_{10} emissions from transportation scenarios in Santa Rosa City for 2020-2030.

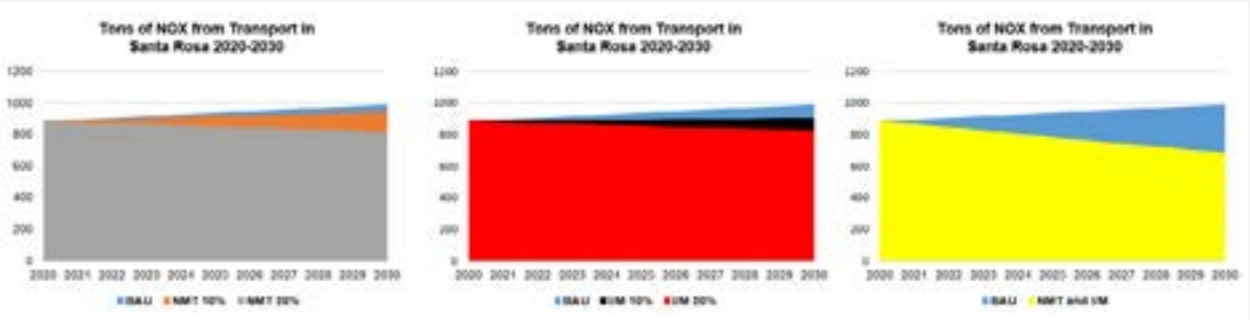

Figure 24: Tons of NO_x emissions from transportation scenarios in Santa Rosa City for 2020-2030.

Photo by Adi Perets on Pexels

Case Study 3

GHANA

Case Study 3

Ghana - 4th National Inventory Report

The CCAC, which developed this guide alongside ICAT, is the only global initiative whose mission is to reduce SLCPs and simultaneously achieve air pollution and climate change benefits. Ghana was one of the six founding members of the CCAC in 2012 and has been at the forefront of efforts over the last decade on national SLCP planning and integration of air pollution and climate change mitigation. The aim of this case study is to focus on one aspect of Ghana's integrated air pollution and climate change planning that provides a practical, real world example of the integration of air pollutants and SLCPs into national GHG inventory reporting. This demonstrates the possibilities of applying the guidance within **Section 4** to facilitate the development of integrated national air pollutant and climate change emission inventories, and highlights the challenges, and advantages and undertaking this integration.

Ghana's motivation to monitor SLCPs and air pollutants within climate change monitoring systems results from the substantial integration of SLCPs and air pollutants in climate change mitigation planning. Air pollution levels in Ghana exceed WHO standards, resulting in thousands of premature deaths per year. Between 2015 and 2019, Ghana went through a National SLCP planning process. Within this process, stakeholders were engaged to raise awareness of SLCPs and integrated air pollution and climate change mitigation strategies, technical analysis was undertaken to assess air pollutant, SLCP and GHG emission reduction potentials from priority mitigation measures, and plans were developed for the implementation of these measures. This SLCP planning process provided the first information on the magnitude of SLCP and air pollutant emissions, alongside GHGs, through the development of an integrated air pollution and climate change mitigation assessment.

Using the LEAP emissions inventory and scenario analysis tool, historical emissions of SLCPs, air pollutants and GHGs were estimated, and projected into the future to assess the reduction in all emissions for different mitigation strategies representing the implementation of different policies and mitigation measures (shown in Table 10), compared to a baseline scenario up to 2040. Example outputs from this assessment are in Figure 25. If Ghana implements the measures included in its NDC, there will be substantial reduction in total CO_2 and CH_4 emissions, but also in black carbon emissions. Additional measures focussing on SLCPs further reduce BC and methane emissions, as well as reducing carbon dioxide emissions further, even though they were not initially included.

The national SLCP planning process in Ghana therefore highlighted that:

i. mitigation of SLCPs can increase climate ambition through direct reduction in SLCPs, but also through additional GHG emission reductions associated with implementation of specific SLCP mitigation measures;

ii. there is substantial air pollution and SLCP mitigation potential that derive from implementation of the measures included in Ghana's NDC, providing local benefits to Ghana from meeting its international climate commitments, and

iii. the integration of different plans and strategies on air pollution and climate change can lead to increased ambition for mitigation of greenhouse gases and improvement of air quality. Further information about Ghana's SLCP Planning Process is available **here**.

Table 10: Mitigation measures included in Ghana's NDC and National SLCP Action Plan.

Sector	Mitigation Measure	Plan or Policy
Energy	50% households using LPG for cooking by 2030	NDC measure
Energy	10% of installed electricity generation capacity renewable by 2030	NDC measure
Forest	40% of regularly burnt areas in savannah and transition zone avoided by 2040	NDC measure
Waste	Promote Adoption of biogas institutional stoves in schools	NDC measure
Transport	800 public buses powered by Compressed Natural Gas (CNG) in four cities in Ghana	NDC measure
Waste	Reduce total amount of waste openly burned by 80% by 2040 compared with 2010 levels	NDC measure
Waste	Recover 350,000 tonnes of methane per year from landfill sites by 2030	NDC measure
Energy	Improved stoves used in 2 million households and 1 million distributed in commercial sector by 2030	NDC measure
Energy	80% grid electricity produced from natural gas-fired power plants instead of heavy fuel oil	NDC measure
Energy	Avoid proposed 770 MW super critical T5 coal plant	NDC measure
Energy	Increase capacity of efficient charcoal kilns by 10% by 2040	NDC measure
Agriculture	Increase by 20% livestock feeding with high quality feed	SLCP Plan measure
Transport	Enforcement of Ghana vehicle emission standards for road transport fleet	SLCP Plan measure
Energy	Increased penetration of more efficient wood and charcoal stoves for cooking	SLCP Plan measure
Industry	Promote using LPG instead of diesel for combustion in the plastic industry.	SLCP Plan measure

The National SLCP Planning process led to the comprehensive integration of SLCPs and air pollutants within Ghana's NDC submitted in 2021 to the UNFCCC in advance of COP26. Ghana's updated NDC commits to mitigate 64 million tonnes CO_2-eq emissions by 2030. In doing so, Ghana's NDC states that a substantial number of co-benefits will be achieved. These include over 2900 avoided premature deaths per year by 2030 from the improvement in air quality that are achieved from the air pollutant and SLCP emissions reductions alongside GHGs. Ghana is one of only a few countries in the world to state quantitatively the health benefits achievable from the implementation of its NDC. Ghana's NDC also outlines packages of Policy Actions that will be implemented to achieve the GHG emission reductions, with those with high SLCP emission reduction relevance specifically highlighted. These Policy Actions include widespread adoption of cleaner

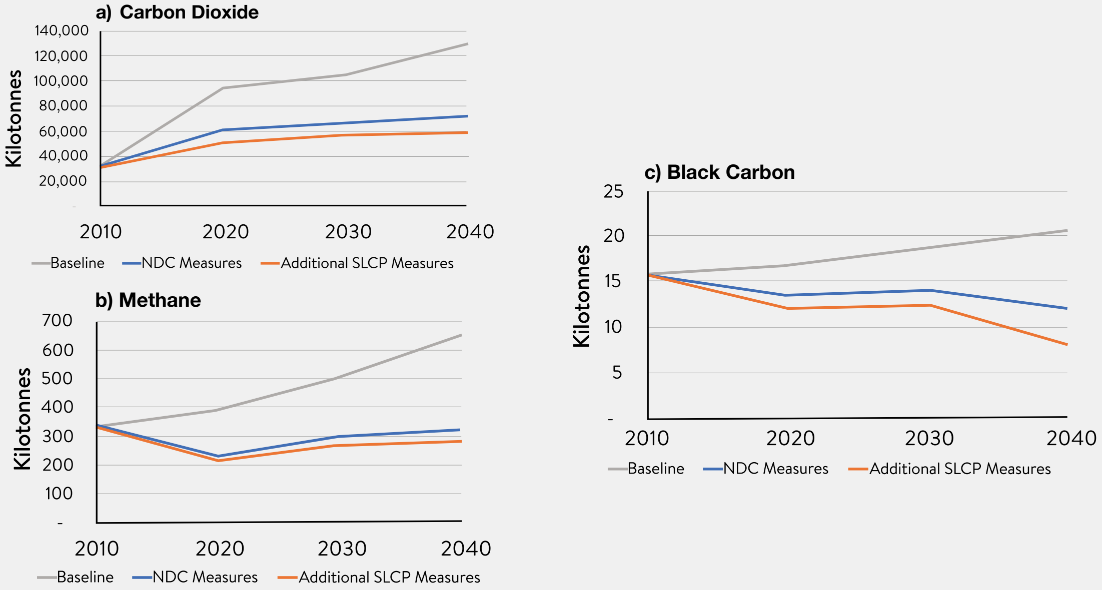

Figure 25: National total emissions of a) carbon dioxide, b) methane and c) black carbon in Ghana between 2010 and 2040 estimated for a baseline scenario (grey line), for the implementation of Ghana's NDC measures (blue line), and for the implementation of the NDC measures and four additional measures included in Ghana's National SLCP Action Plan (orange line).

cooking solutions, sustainable charcoal production, and the adoption of improved solid waste management and reducing fugitive methane emissions from oil and gas infrastructure.

The commitments that Ghana has made in its climate change planning related to SLCPs and air pollution mitigation provide motivation to simultaneously track progress on GHGs, SLCPs and air pollutants. Since 2018, Ghana has been reporting SLCP and air pollutant emissions to the UNFCCC alongside GHGs within its national GHG emission inventory. Ghana's second Biennial Update Report was the first of its national GHG inventories to include SLCP and air pollutant emissions. SLCP and air pollutant emissions have been updated in its Fourth National GHG Inventory Report (submitted in 2019), and Fifth National GHG Inventory Report (submitted in 2022).

The Ghana Environmental Protection Agency has overall responsibility for the development of Ghana's National GHG emission inventory and is therefore the organisation responsible for the integration of SLCPs. As part of the national GHG emission inventory development process, data collection procedures and the inventory development team encompasses institutions that collect necessary activity data for the development of a GHG emission inventory. This includes Ghana's Energy Commission, Ministry of Transport, Forestry Commission, and Ministry of Food and Agriculture. These organisations provide data to the Ghana EPA, who integrate it into spreadsheets based on the IPCC GHG emission inventory methodologies to estimate national GHG emissions. The provision of activity data from key national institutions for estimating national GHG emissions makes the integration of SLCPs and air pollutants into the national GHG emission inventory a more efficient process compared to the development of a standalone SLCP and air pollutant emission inventory. This is due to the substantial overlap in activity data necessary to estimate emissions of SLCPs and air pollutants and GHGs, as highlighted in **Section 3**.

Also emphasised in **Section 3** are those sectors and considerations for which different methods, and approaches are required for SLCPs and air pollutants compared to GHG emission inventories. In Ghana, the integration of SLCP and air pollutant emissions within the GHG development process means that these considerations can be integrated into the existing data requests and inventory development system, rather than having to build and existing system. For example, in the transport sector, estimation of SLCP and air pollutant emissions required an understanding of the vehicle emission control technology (e.g. Euro standards) present in the vehicle, while for GHGs only the total vehicle fuel consumption is necessary. Data is available in Ghana from vehicle inspection and maintenance data on the year of manufacture of vehicles, which can be used as a proxy for likely Euro standards in the absence of more specific data. This additional data is provided alongside other key statistics, like fuel consumption and the composition of the vehicle fleet, within the transport sector data provision for the national GHG inventory. It is then integrated into a modified Excel spreadsheet which allows it to be used to estimate SLCP and air pollutant emissions from transport, alongside, and consistent with, GHG emission estimates. In contrast to the Ghana-specific data that is available for the majority of GHG, SLCP and air pollutant emitting source sectors, emission factors that have been measured in Ghana, or other representative countries, are not available for the majority of sectors. As a result, the development of the SLCP and air pollutant emission estimates for Ghana required the use of default international emission factors alongside country-specific activity data to allow for the development of national SLCP and air pollutant emission estimates.

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Figure 26 and Table 11 show the national total SLCP and local air pollutant emissions for Ghana from the recent fifth National Inventory Report. The advantages, value and opportunity that Ghana gets from the integration of SLCPs and air pollutants within this inventory include:

- Baseline against which impact of policies and measures can be evaluated.
- Identification of major sources.
- Trends in SLCPs and air pollutants can be assessed.

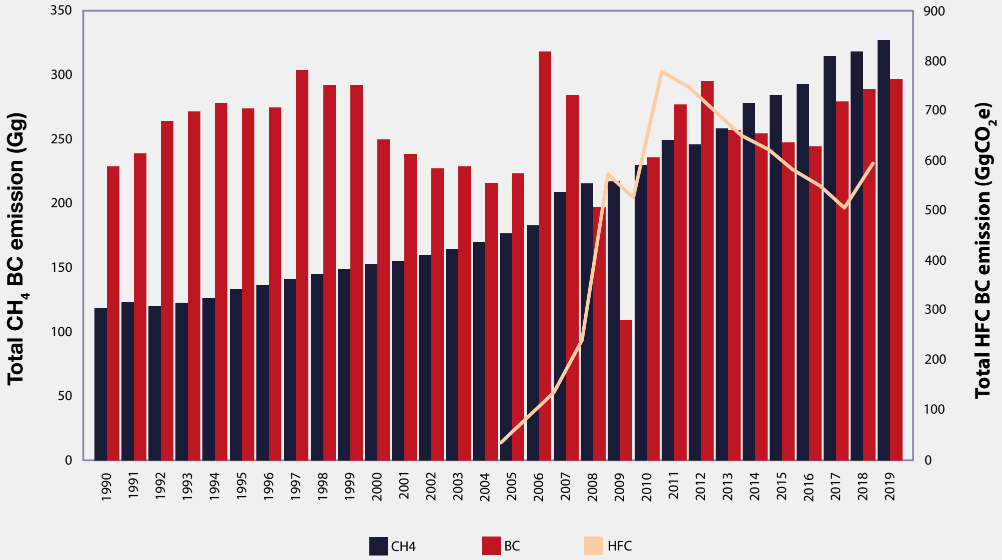

Figure 26: National total SLCP emissions for Ghana between 1990 and 2019 (Source: Ghana's Fifth National Inventory Report).

Table 11: Local air pollutant emissions in Ghana 1990-2019 from Ghana's National GHG emission inventory (Source: Ghana's Fifth National Inventory Report).

Year	Gg/year					
	NO_x	CO	NMVO	BC	$PM_{2.5}$	SO_2
1990	26.8	805.9	166.9	229.3	2,148.7	74.3
1991	28.0	839.5	174.7	239.6	2,237.5	74.7
1992	47.0	871.9	183.4	264.9	2,333.8	127.7
1993	47.4	902.7	191.1	271.8	2,400.2	129.4
1994	47.8	934.5	198.9	279.0	2,470.5	134.6
1995	34.5	960.0	203.5	274.7	2,535.8	101.5
1996	33.2	988.3	209.2	276.1	2,612.4	102.8
1997	39.9	1,024.4	216.3	304.5	2,762.0	129.1
1998	42.2	1,018.6	216.8	293.5	2,667.1	139.0
1999	39.2	1,028.0	219.8	293.5	2,698.7	127.9
2000	32.8	793.4	142.0	250.5	2,411.4	82.3
2001	33.7	768.7	138.7	239.4	2,294.0	79.9
2002	35.9	750.5	137.3	228.4	2,182.4	86.8
2003	35.6	699.3	133.1	230.1	2,094.0	102.5
2004	35.6	737.2	139.0	217.1	2,035.8	86.9
2005	39.5	835.8	175.6	224.0	2,038.2	117.3
2006	46.8	1,068.1	210.0	319.7	3,011.6	132.3
2007	52.6	955.9	200.2	285.2	2,490.2	164.7
2008	41.5	822.2	178.5	198.3	1,814.6	104.3
2009	43.5	661.3	157.1	109.9	927.3	107.7
2010	72.6	913.5	201.1	236.4	1,897.6	189.4
2011	74.1	1,088.5	231.1	277.8	2,420.1	188.2
2012	92.0	1,100.9	235.1	295.9	2,380.9	234.8
2013	88.4	1,084.2	237.0	258.1	2,097.2	217.3
2014	83.7	1,125.8	245.1	254.7	2,161.5	195.3
2015	82.7	1,121.4	244.1	248.7	2,142.8	190.0
2016	77.1	1,106.7	241.7	245.3	2,126.9	191.4
2017	94.7	1,047.9	208.0	280.3	2,319.2	219.6
2018	108.0	1,357.8	302.6	290.2	2,366.1	237.0
2019	115.0	1,168.5	232.0	297.7	2,394.8	241.1

Case Study 4

COLOMBIA

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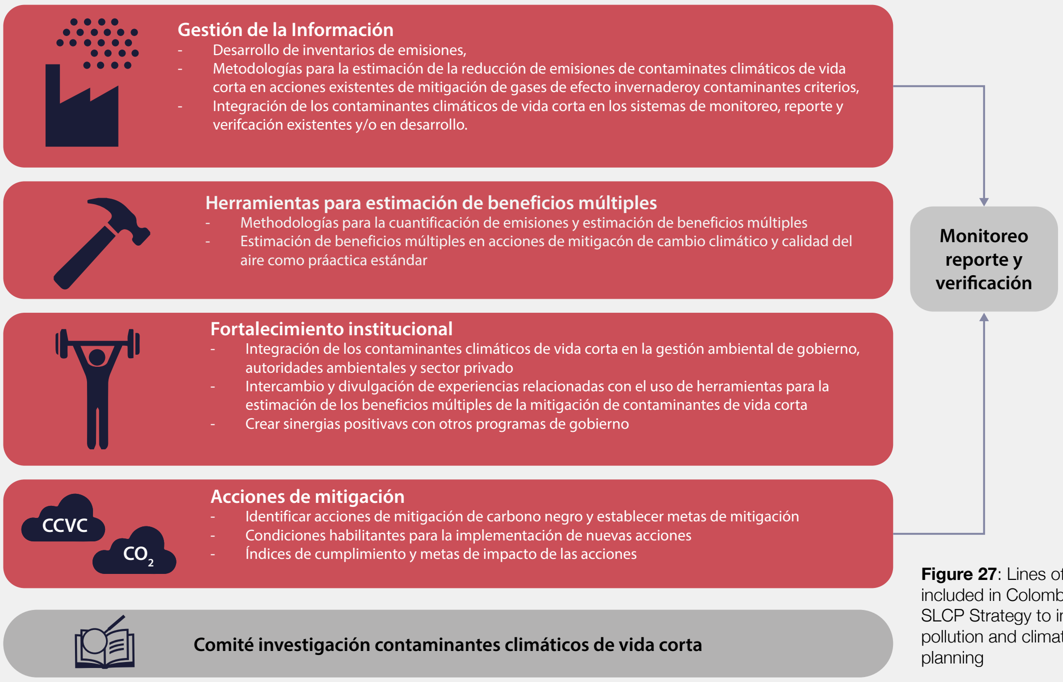
Case Study 4

Colombia - National BC Emission Inventory

Colombia has undertaken national planning on SLCPs since 2013. Over the past decade, Colombia has implemented many of the approaches and methods included within this guide, including the development of a national inventory on BC and air pollutants (**Section 3**), which it has used to include quantitative targets on SLCPs within its climate change mitigation commitment. The aim of this case study is to briefly highlight the approach Colombia has taken to the development of an integrated air pollution and climate change emission inventory,and how this has facilitated target-setting, and identification of mitigation actions in Colombia. The case study then highlights how Colombia has extended and used this integrated approach to estimating GHG, SLCP and air pollutant emissions to the quantification of the health benefits from the implementation of Colombia climate change plans, using an approach consistent with that outlined in **Section 5** of this guide.

National SLCP Action Planning in Colombia

National SLCP Planning in Colombia has been coordinated jointly by the Environmental, Sectoral and Urban Affairs Directorate, and the Climate Change and Risk Management Directorate of the Ministry of Environment. During the initial National SLCP Planning project, the key output was a National Strategy on SLCPs. The development of Colombia's National SLCP Strategy began in 2016, was published in 2020 and provides a focus for actions to achieve the integration of air pollution and climate change mitigation planning through a specific set of objectives and goals. One of these objectives was the development of a black carbon emission inventory that was consistent with the national GHG emission inventory.



Gestión de la Información
- Desarrollo de inventarios de emisiones,
- Metodologías para la estimación de la reducción de emisiones de contaminates climáticos de vida corta en acciones existentes de mitigación de gases de efecto invernaderoy contaminantes criterios,
- Integración de los contaminantes climáticos de vida corta en los sistemas de monitoreo, reporte y verifcación existentes y/o en desarrollo.

Herramientas para estimación de beneficios múltiples
- Methodologías para la cuantificación de emisiones y estimación de beneficios múltiples
- Estimación de beneficios múltiples en acciones de mitigacón de cambio climático y calidad del aire como práactica estándar

Fortalecimiento institucional
- Integración de los contaminantes climáticos de vida corta en la gestión ambiental de gobierno, autoridades ambientales y sector privado
- Intercambio y divulgación de experiencias relacionadas con el uso de herramientas para la estimación de los beneficios múltiples de la mitigación de contaminantes de vida corta
- Crear sinergias positivavs con otros programas de gobierno

Acciones de mitigación
- Identificar acciones de mitigación de carbono negro y establecer metas de mitigación
- Condiciones habilitantes para la implementación de nuevas acciones
- Índices de cumplimiento y metas de impacto de las acciones

Comité investigación contaminantes climáticos de vida corta

Monitoreo reporte y verificación

Figure 27: Lines of action included in Colombia's National SLCP Strategy to integrate air pollution and climate change planning

Colombia's first BC emission inventory was developed in 2016 and was endorsed and published by the institution also responsible for the national GHG emission inventory in 2016 (Institute for Hydrology, Meteorology, and Environmental Studies (IDEAM)). The development of the BC emission inventory also included other air pollutants, and while not developed with the national GHG emission inventory, used a consistent set of data and statistics, similar to the approach and methods outlined in **Section 3**. As a result of developing the BC emission inventory, Colombia was able to establish a target for the reduction of black carbon within its updated NDC submitted in 2020.

For GHGs, the regular development of national GHG emission inventories provides a reference against which GHG emission reductions can be framed and stated in documents like NDCs. The development, and endorsement of a national BC emission inventory by IDEAM provided the corresponding reference point against which a black carbon target could be set (IDEAM, 2020). This is shown in the 2020 NDC, in which the BC reduction target is a reduction of 40% compared to 2014 levels (Government of Colombia, 2020). The 2014 black carbon emissions were those published by IDEAM in the national BC emission inventory. A national institution such as IDEAM developing this inventory meant that as well as providing the emission levels for setting the target, there is a national institution capable of, and responsible for updating the national emission inventory for BC at regular intervals to monitor BC emissions against the target as the NDC is implemented.

The development of an integrated inventory, as outlined in **Section 3**, in Colombia also meant that this inventory could not only inform climate change planning, but also air quality planning, and facilitated alignment between solving climate change and air pollution. In 2019, Colombia released their first National Strategy on Air Quality. In it, the national emission inventory of BC and other air pollutants was used as the basis for identifying the major air pollution sources that require control, meaning that the basis for the actions in the strategy is consistent with the underlying information used to set the NDC black carbon target (Colombia Ministry of Environment and Sustainable development, 2019).

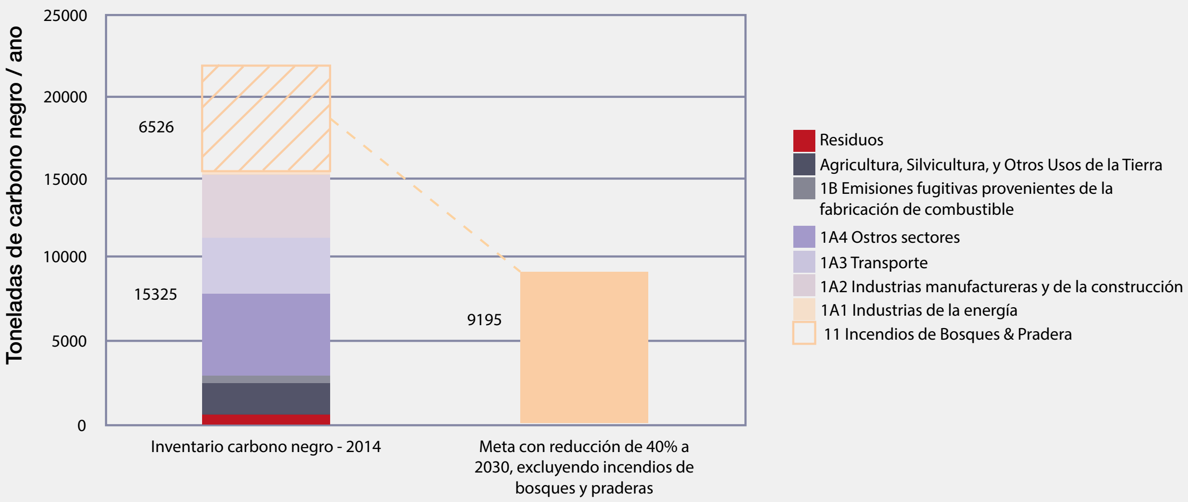


Figure 28: Black carbon target included within Colombia's updated NDC (Source: Colombia NDC Update 2020).

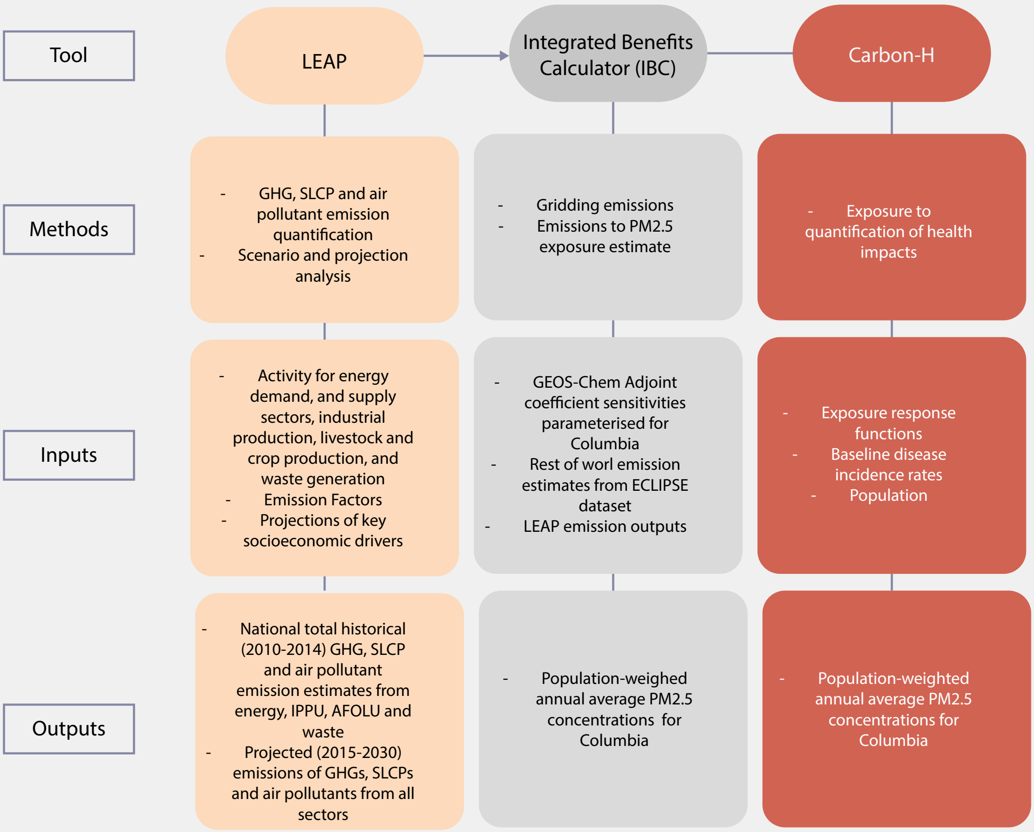
Quantifying Health Benefits of climate change action

Having established a target to reduce BC within its NDC, Colombia was also interested in understanding the magnitude of the benefits achievable through the implementation of the NDC. The Ministries of Environment and Health of Colombia therefore, collaborating with the WHO undertook an air pollution health impact assessment as outlined in **Section 5** to quantify the health benefits achievable from air pollution emission reductions from the implementation of the updated NDC.

The overall modelling framework used to quantify the health benefits that could be achieved from the implementation of Colombia's NDC is shown in Figure 29. As described in **Section 5** in general, the modelling framework to quantify the health benefits of air pollution in Colombia characterises the link between:

i. emissions of air pollutants;
ii. their transport and chemical reactivity in the atmosphere that determines levels of exposure to fine particulate matter ($PM_{2.5}$);
iii. the consequences of this exposure on the incidence of fatal and non-fatal health outcomes; and
iv. the economic impact of these air pollution-attributable health impacts.

The emissions, exposure, health and economic impacts are characterised for historical years (2014), and for future projections up to 2030 for different scenarios. The 2030 baseline scenario reflects the magnitude of these variables in Colombia for a scenario that projects socioeconomic development in the country to continue according to the current trajectory, without the implementation of policies and measures that



Tool	LEAP	Integrated Benefits Calculator (IBC)	Carbon-H
Methods	- GHG, SLCP and air pollutant emission quantification - Scenario and projection analysis	- Gridding emissions - Emissions to PM2.5 exposure estimate	- Exposure to quantification of health impacts
Inputs	- Activity for energy demand, and supply sectors, industrial production, livestock and crop production, and waste generation - Emission Factors - Projections of key socioeconomic drivers	- GEOS-Chem Adjoint coefficient sensitivities parameterised for Columbia - Rest of worl emission estimates from ECLIPSE dataset - LEAP emission outputs	- Exposure response functions - Baseline disease incidence rates - Population
Outputs	- National total historical (2010-2014) GHG, SLCP and air pollutant emission estimates from energy, IPPU, AFOLU and waste - Projected (2015-2030) emissions of GHGs, SLCPs and air pollutants from all sectors	- Population-weighed annual average PM2.5 concentrations for Columbia	- Population-weighted annual average PM2.5 concentrations for Columbia

Figure 29: Modelling framework to undertake health impact assessment of Colombia's Nationally Determined Contribution

are specifically designed to reduce emissions. The 2030 mitigation scenarios reflect futures in which packages of policies and measures included in Colombia's NDC are implemented. The difference in magnitude of the emissions, exposure, health and economic impacts in the future scenarios therefore allowed the benefits from implementing the mitigation measures in Colombia's NDC to be determined. The 2030 baseline scenario provides a reference point against which the different mitigation scenarios can be compared in terms of air pollution health and economic impacts. The following sections describe the methods used specifically in Colombia to undertake each of the three steps in the analysis.

Step 1

Quantify air pollutant and SLCP emission reductions from implementation of NDC measures

First, emissions of air pollutants in historic and future years were estimated using the LEAP tool, see below. LEAP has been widely used for GHG mitigation assessments, including for NDCs, and is increasingly used for integrated air pollution and climate change mitigation analyses. For Colombia's NDC, LEAP was the tool selected to quantify the GHG emission reduction potential of different mitigation measures being considered for inclusion in the NDC. Integrating air pollutant emissions into LEAP allowed for the development of consistent estimates of GHG, SLCP and air pollutant emissions (as outlined in **Section 3**). This ensured that the air pollutant emission reductions from implementation of the mitigation measures included in the NDC were consistent (i.e. reflecting the same historic data and future projections) with the GHG emission reduction potential included in the NDC. As outlined in **Section 3**, the key equation used to estimate emissions from all major sources is the multiplication of an activity variable by an emission factor. The activity variable quantifies the scale of a particular sector or process is in a country (e.g. the number of Terajoules of fuel consumed in a particular sector, the number of tonnes of production of a particular mineral, chemical or other product). Emission factors quantify the mass of pollutant emitted per unit of activity (e.g. the kilograms of BC emitted per Terajoule of fuel consumed). A LEAP analysis was developed to quantify GHG emission reductions that provided the basis for the GHG reduction targets included within the NDC. To undertake the air pollutant mitigation assessment, emission factors were added to the GHG LEAP analysis for all pollutants contributing to $PM_{2.5}$ concentrations in the atmosphere, both primary $PM_{2.5}$ emissions, and gaseous pollutants that react in the atmosphere to produce $PM_{2.5}$, to allow annual average $PM_{2.5}$ concentrations, and health impacts to be estimated.

Step 2

Convert emissions to changes in concentrations

The next stage is the conversion of national total air pollutant emissions into estimates of ambient $PM_{2.5}$ concentrations relevant for human health impacts. The LEAP tool has been designed to provide a relatively simple method for this conversion at the national scale, for application where more detailed methods, such as the use of atmospheric chemistry transport models, are not available (see **Section 5** for further details). For Colombia, the LEAP model output emissions of air pollutants for historical years (2014) and for projections (2015-2030) for a baseline scenario, and mitigation scenarios reflecting the implementation of climate change mitigation measures included in Colombia's NDC. To link the emissions in each of these scenarios to changes in exposure to particulate matter, the air pollutant with the largest burden on human health, the Integrated Benefits Calculator (IBC) within LEAP was used.

The IBC module takes national total emissions for a target country (i.e. Colombia) and converts them into estimates of air pollution exposure. The exposure metric used is the population-weighted annual average $PM_{2.5}$ concentration for Colombia. Population-weighted annual average $PM_{2.5}$ concentrations were estimated by combining the emissions estimated in LEAP for each $PM_{2.5}$ and $PM_{2.5}$-precursor pollutant for Colombia in each year and scenario with outputs from an atmospheric chemistry transport model, GEOS-Chem Adjoint. National total emissions of primary $PM_{2.5}$ (BC, OC or other primary PM emissions), and secondary inorganic $PM_{2.5}$ precursors (NO_x, SO_2 and NH_3) derived using LEAP for the target country were spatially distributed into 2° x 2.5° grids covering the country to match the scale of the GEOS-Chem Adjoint model results. Emissions from the rest of the world are represented by an international global emission inventory.

Next, to translate gridded emissions to population-weighted annual average $PM_{2.5}$ concentrations, accounting for transport and chemical processing in the atmosphere, the gridded emissions are combined with output from the GEOS-Chem global atmospheric chemistry transport model (Bey et al., 2001; Henze et al., 2007). The GEOS-Chem Adjoint model output quantifies the relationship between emissions of a particular pollutant that contributes directly to $PM_{2.5}$ (BC, OC or other PM), or is a precursor to $PM_{2.5}$ (NO_x, SO_2 and NH_3) in any location, and the associated change in $PM_{2.5}$ in Colombia. These outputs from the GEOS-Chem adjoint are output as gridded 'coefficients', which are then multiplied by emission estimates to estimate the change in population-weighted annual average $PM_{2.5}$ concentrations in Colombia for each year and emission scenario.

Step 3

Apply concentration-response function with health data to estimate avoided mortality.

With annual average national $PM_{2.5}$ concentrations estimated for historical and future years, the impact on human health were estimated using the World Health Organisation's CarbonH tool. Within Carbon H, the estimate of $PM_{2.5}$ exposure was combined with population, baseline incidence rates for diseases associated with air pollution exposure, and exposure-response functions to estimate the health burden attributable to $PM_{2.5}$ exposure for 2014, and for future years in the baseline and mitigation scenarios, as outlined in **Section 5** of this guide.

The exposure-response functions characterise the relationship between exposure to air pollution, and negative health outcomes. In Colombia, premature mortality from different diseases associated with air pollution were quantified, alongside morbidity outcomes, i.e. non-fatal health impacts such as asthma exacerbations and chronic bronchitis. Exposure-response relationships are derived from epidemiological studies in which a population's air pollution exposure and health status are assessed. In Latin America, as well as Asia and Africa, these studies are not common compared to North America and Europe, meaning that country- or region-specific exposure-response functions are often not available, including in Colombia. In this case, exposure-response functions from European studies were applied to the Colombian population in the absence of local relationships.

The results from this assessment indicate that implementation of Colombia's NDC could avoid 3,500 premature deaths per year in 2030 compared to the baseline scenario (approximately 10% fewer premature deaths than in the baseline scenario). This underlines that implementation of the policies and measures that underpin the NDC can not only reduce Colombia's GHG emissions by 50% in 2030 compared to the baseline scenario, but can also substantially improve human health. To achieve Colombia's NDC requires that the mitigation measures identified to achieve the NDC are implemented, including 12 measures specifically targeting SLCPs and air pollutants. The quantification of the health benefits from these measures provides further evidence and motivation to accelerate implementation of these measures and can broaden the coalition of support for their implementation. This is shown in this case study for Colombia, as the health impact assessment included the Ministry of Health in climate change mitigation planning for the first time.

Case Study 5

NORWAY

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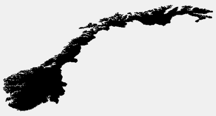
Case Study 5



Norway – Perspectives of a National Focal Point

Authors: Vigdis Vestreng (Norwegian Environment Agency), Richard Claxton (Aether), Luke Jones (Aether), Justin Goodwin (Aether)

Norway has developed an integrated approach to its consideration of GHGs and SLCPs over the past ten years, spearheaded by the work of Vigdis Vestreng who works for the Norwegian Environment Agency (NEA) in the Climate Science and Air Quality section. Her role is to provide advice on climate policies and measures to reduce emissions of GHGs and SLCFs, and she has worked to advance Norway's treatment of SLCFs and air pollution in a more integrated fashion, since moving to NEA from the Norwegian Met Office in 2008. Vigdis worked on the first black carbon inventory in 2012 and SLCF action plan in 2013 and continues to have an advisory role in climate and SLCF policy development. Nowadays, Vigdis leads a team of 5-6 colleagues who use part of their time on SLCFs, reflecting the strengthened focus on SLCFs in Norway. Although she now works as a policy advisor, Vigdis continues to have strong connections with those who are working on inventory compilation, providing validation and quality assurance. The following section is an interview with Vigdis which delves deeper into the mechanisms and results of a more integrated system in Norway.

What is the background to Norway's integrated approach and what sectors, tools, approaches are available to maintain this approach?

Since joining the NEA in 2008, I have worked on building the understanding of short-lived climate forcers in Norway through the development of inventories, action plans, and helping to integrate their emissions calculations into the wider GHG inventory system. When we started work in this area, SLCFs were a relatively new field in public administration: the basis of scientific knowledge was still immature and had to develop in parallel with work to estimate emissions and develop a SLCF action plan.

In 2012, we developed a first BC emissions inventory with Statistics Norway. These days, the EMEP/EEA Guidebook offers some insight into ratios that can be applied to PM emissions to estimate BC for different sources, but when we worked on this, such information was unavailable. Instead, we had to develop our own methodology for all sources, building from methodologies and calculations included within the IIASA GAINS model but also developing our own country-specific emission factors for some major sources, notably residential woodburning.

Following on from this work, the Norwegian Environment Agency in 2013 performed an integrated assessment of climate, health, and environmental effects of Norway's SLCF emissions, proposed measures and instruments for reducing such effects by 2030, and evaluated the need for additional monitoring of these components. The SLCFs considered included BC, tropospheric ozone (O_3) with its precursors other than methane and some HFCs. Methane and HFCs were already regulated under the Kyoto Protocol, but requirements to report emissions of BC did not exist and so this went beyond the standard reporting requirements of an inventory team to develop. In addition to the SLCFs which warms the atmosphere, the cooling effect of some air pollutants, including organic carbon (OC) and sulphur dioxide (SO_2) was considered in order to cover more short-lived forcers, and be able to assess the net climate effect of mitigation measures.

As there is no international consensus over what emissions metric is, most suitable for comparing emissions of SLCFs on a like-for-like basis (akin to CO_2e), we developed a Norway-specific emissions metric, GTP10 (Norway), which estimates global temperature change potential calculated ten years after the emission occurred in Norway. A Norway-specific metric was helpful because a characteristic of the climate effects of the SLFCs, with the exception of some HFCs and (to a lesser extent) CH_4, is that it matters where in the world the emissions are released. The use of GTP10 enabled the comparison of existing and potential policies and actions that are being targeted to reduce emissions of CO_2 primarily and is still utilised to inform decision-makers today. It enabled the quantification of the co-benefits of existing climate policies and the identification of the main opportunities to further reduce BC and methane emissions in Norway. For example, in 2016, a report by the Norwegian Environment Agency found that existing climate targets for 2030 would reduce BC emissions by 10% in 2025 compared to 2013 levels, but with additional measures the impact could be increased to 23%. Recent analysis has shown that the full implementation of measures to cut BC and methane emissions under the Arctic Council would reduce BC emissions by 28% against the 2017 baseline with the accelerated introduction of modern woodburning stoves and pellet burners and electrification of ferries and passenger ships found to have the greatest impact.

Since then, I have continued to work on black carbon and working to promote its importance. Some countries are focussed more on reducing emissions from SLCFs like BC, whilst others are more driven by Paris Agreement and emissions for GHGs. In Norway, assessment of GHGs and SLCFs have been getting more integrated over the past decade due to efforts of my team.

What are the main problems that involve GHG/SLCP and air pollutants?

In Norway, projections show that what might be expected to be major sources of BC elsewhere in world will largely be resolved by 2030: emissions from road transport are projected to have declined significantly. Instead, focus is turning to other sources of emissions, particularly domestic wood combustion.

As CO_2 emissions from domestic wood combustion are biogenic in origin and accounted for in the Land Use, Land Use Change and Forestry (LULUCF) sector in current GHG emissions inventories, the impact on climate change is often overlooked. Inventories typically currently report GHG emissions using a global warming potential (GWP) over 100 years to express the relative impact of different pollutants. However, on a shorter timescale, other pollutants can be more important. For example, BC has a large short-term warming impact on the climate which is not considered in typical GHG emissions inventories as reported to the UNFCCC. Having said this, we have shown in our assessments that CO_2 also has a large climate impact in the short-term. As wood combustion is a major source of BC, reducing emissions from it can have a significant short-term impact on global warming. At the same time, wood combustion is a major source of harmful air pollutants, such as particulate matter, polycyclic aromatic hydrocarbons (PAHs), and methane (which can lead to secondary pollution of ozone). This highlights the importance of considering GHGs, SLCFs, and air pollutants together. Action to discourage domestic wood combustion and promote clean stoves would have significant co-benefits to reduce both BC and methane. The reduced CO_2-emissions from biofuel will however not be included in the calculations according as the impact on emissions of CO_2 when considered with a 100-year GWP is zero.

Additionally, methane from agriculture continues to be an issue, not just in Norway but globally. An important factor in agricultural methane emissions, is the oxidation of methane and the formation of tropospheric ozone. Ozone is not just an air pollutant that has a direct impact on human health, but it also is damaging to food production.

Beyond Norway, it is likely that for other countries, particularly non-Annex I countries, the most important sources to address, are likely to be the emissions from power generation and from road transport. Addressing these emissions will have a positive impact on the reduction SLCFs and air pollutants. At the same time, however, the adoption of a more integrated approach will enable the identification of additional sources, such as wood combustion, which contribute to short-term global warming and air quality, and therefore earlier action to mitigate.

What does the integrated emissions inventory include?

In Norway, the integrated emissions system is hosted by a specially designed tool which enables the input of activity data, emission factors, and then calculates emissions of GHGs and air pollutants together. Such a tool, whilst having a high upfront cost to develop, allows for easier updates on an annual basis. It also ensures the use of consistent fuel balances, assumptions, and methodologies between GHG and air pollutant inventory compilation. Whilst this tool has been specifically designed for Norway's purpose, other tools and systems can be used, such as the development of suite of spreadsheets and/or databases which offer the same consistency.

The data can then be exported in a way that allows for easier quantification of the impact of actions on GHGs and air pollutants., The calculations of CO_2 remains somewhat simpler than the calculations of specific air pollutants as more detailed emission factors and activity data is required for SLCFs. Therefore, we have often identified data gaps and errors when looking at the GHG-measures from an SLCF angle. A framework for consideration of all pollutants and GHGs is the important thing.

What decision making can this integration of analysis on GHG/ SLCF and air pollutants support?

Decision-makers currently focus on overarching goals and requirements such as meeting reporting and targets developed under the Paris Agreement, SDGs, or meeting emissions limit and/or air quality requirements (e.g., WHO guidelines on air quality standards). There is, however, a need for a more holistic consideration across GHGs, SLCFs, and air pollutants in order to utilise potential co-benefits.

In Norway, the integrated emissions calculation tool enables joined up thinking, and policies can now be assessed for the impact on human health, impact on achieving SDGs, and the impact on the emissions of GHGs and SLCFs.

The Climate and Environment Ministry itself has encouraged integrated work. As a part of an agency under the Climate and Environment Ministry, we provide advice and do assessments when requested by the Ministry, using the integrated emissions calculation tool as a key evidence base. The integrated tool is also available online, along with climate reports and seminars, ensuring accessibility and transparency for the general public.

What key messages and benefits can come out of integrated analysis of GHG and SLCPs?

When GHG measures were first assessed for their impact on the emissions of SLCFs a couple of years after the development of Norway's action plan on SLCFs, it was found that many of the measures, principally designed to reduce carbon emissions, would reduce emissions of SLCFs more than the targeted measures, with the major exception of wood burning.

What are the key aspects of a strong integrated approach to clean air and climate action?

Emissions inventories are the backbone of a strong, integrated approach to action development and mitigation. An undervalued aspect is the fostering of a shared notion that urgent action is required, and this has been key to continued strength of belief in an integrated approach in Norway. By understanding the short-term climate effects of all pollutants, we are able consider these impacts for all actions and not just climate related. Without this urgency, we would miss opportunities to reduce our climate impact. The benefit is that policymakers are also able to readily identify actions that have the potential to mitigate climate change, have a healthier population, and improve food production. This is a huge advantage for the public, nature and the world.

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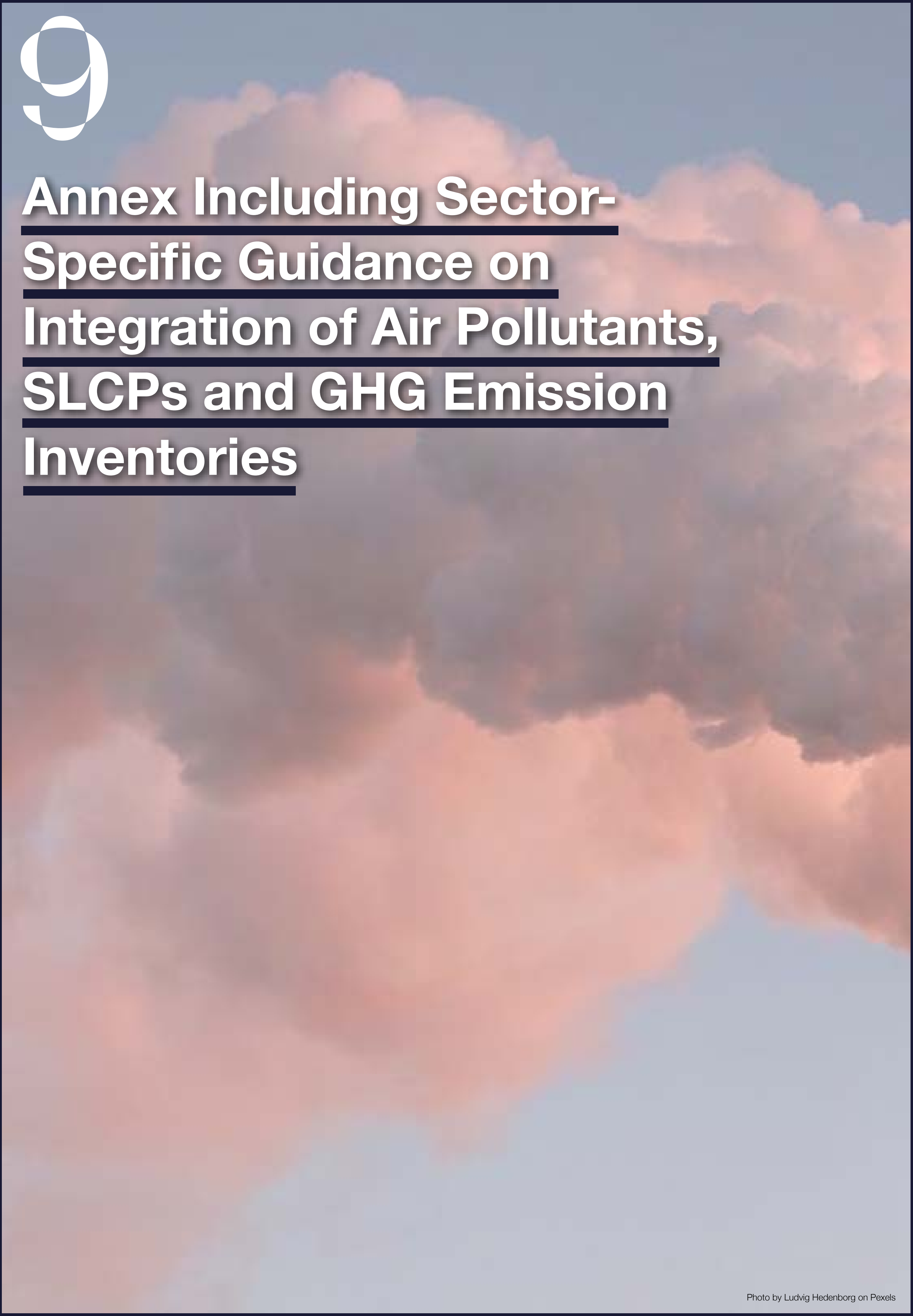
9

Annex Including Sector-Specific Guidance on Integration of Air Pollutants, SLCPs and GHG Emission Inventories



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Energy

Table A1: Summary of key considerations for quantification of SLCP and air pollutant emissions in energy sub-sectors.

Sector: Transport

Sub-categories that emit SLCPs and air pollutants:

- **Road Transport**
- **Rail**
- **Shipping**
- **Aviation**

Key considerations on integration of SLCPs and air pollutants into emission assessments

The transport sector includes road, rail, shipping and aviation transport modes. SLCP and air pollutants are emitted from the exhaust of vehicles, vessels, planes and trains during their operation. The magnitude of exhaust emissions depends on the type and quality of fuel used as well as the emission control technology fitted to the vehicle (e.g., the Euro standard that vehicles are manufactured to meet for road transport). Particulate matter air pollution is also emitted from road dust suspension, and brake abrasion as vehicle drive along roads. Finally, electric vehicles do not have exhaust emissions associated with them but do have road dust and brake abrasion emissions, and charging them may also contribute to SLCP and air pollutant emissions if the electricity is generated using non-renewable sources (i.e., fossil fuels or biomass). Emissions from electricity generation are considered under the Electricity Generation sub-category, which is describes in more detail below. When quantifying the magnitude of the SLCP and air pollutant emissions from transport from these sources, key considerations include:

Vehicle fleet and vehicle emission standards:

For road transport, GHG emissions are often calculated using a Tier 1 approach by multiplying total fuel consumption by a fuel-specific emission factor. Carbon in fuel is a major contributor to GHG emissions and carbon contents are relatively consistent for different fuel types globally. In Europe, the United States, China, and other regions, there have been increasingly stringent vehicle emission standards in place since the 1990s. The technology mandated by the vehicle emission standards, such as diesel particle filters (DPFs) substantially reduce the emissions of particular pollutants (e.g., $PM_{2.5}$, BC in the case of DPFs) compared to those vehicles where the technology is not fitted.

The Tier 1 approach to quantifying SLCP and air pollutant emissions from road transport is consistent with the IPCC approach, in which the activity variable is the total gasoline, diesel, biofuel, CNG, LPG or other fuel used in road transport, multiplied by fuel-specific emission factors. However, this Tier 1 approach does not account for the significant range of emission intensities from vehicles of different age meeting different vehicle emission standards within the vehicle fleet.

Therefore, it is recommended, where possible that a Tier 2 approach to SLCP and air pollutant emissions are used to quantify road transport emissions. This requires additional data, that may not be collected when developing a stand-alone GHG emission inventory, specifically:

- Breakdown of the vehicle fleet by vehicle type (e.g. passenger cars, light commercial vehicles, heavy duty vehicles, motorcycles).
- The percentage of vehicles of each type with in different age groups and conforming to different vehicle emission standards (e.g. Euro standards).
- Average distance travelled by vehicle type per year.
- Average fuel efficiency of vehicles of each type.

The EMEP/EEA air pollutant emission inventory guidelines include default emission factors for different vehicle types for each of the Euro standards, that can be applied with the activity data described above.

Fuel Quality

The sulphur content of fuels used in road transport are important for the calculation of sulphur dioxide (SO_2)emissions, as outlined above for the energy sector in general. However, in addition to determining SO_2 emissions from road transport, the sulphur content of the vehicles can also affect the performance of specific emission control technologies fitted to vehicles that meet, e.g. Euro 5 or Euro 6 standards. Therefore, if the sulphur content of the fuel used in vehicles exceeds limits for the operation of emission control technology (typically 10-50 ppm sulphur content for Euro 6 vehicles), then this could also increase the emissions associated with the operation of these vehicles.

Non-exhaust air pollutant emissions

In addition to the more detailed activity data recommended to accurately estimate air pollutant and SLCP emissions from vehicle exhaust, road transport also has an additional air pollutant emission source, that is not relevant for the quantification of GHG emissions. In countries where exhaust air pollutant emissions from vehicles are increasingly stringently regulated, non-exhaust emissions from tyre and brake wear are contributing a larger fraction of the total particulate matter emissions from road transport. Tyre and brake wear emissions are emitted from vehicles regardless of the fuel, and are therefore also a source of air pollutant emissions from electric vehicles.

The EMEP/EEA Tier 1 methodology from non-exhaust road transport emissions includes the number of vehicles of different types as the activity variable, and can therefore be relatively easily applied with the EMEP/EEA methods for exhaust air pollutant and SLCP emissions. The Tier 2 method accounts for the average speeds that vehicles travels, which is a determining factor in the magnitude of non-road emissions

Key Data Sources to integrate SLCPs and air pollutants

- EMEP/EEA air pollution emission inventory guidebook for emission factors
- UNEP Global Sulphur Progress Tracker

Sector: Residential/Commercial

Sub-categories that emit SLCPs and air pollutants:

- **Cooking/heating fuels/technologies**
- **Stationary fuel combustion (e.g. diesel generators)**

Key considerations on integration of SLCPs and air pollutants into emission assessments

The residential sector and commercial sector emit SLCPs and air pollutants from fuel combustion and indirectly via electricity consumption. The indirect emissions from electricity consumption are considered under the electricity generation sub-category described below. For direct fuel consumption SLCPs and air pollutants are emitted from combustion of fossil fuels, which also directly emits GHGs. Combustion of biomass is also a major source of air pollutant and SLCP emissions, which does not directly emit GHGs, but may contribute to net-CO_2 emissions through deforestation and land degradation. Integrating SLCP and air pollutants within GHG emission estimates includes the following key considerations:

Importance of biomass combustion

The combustion of solid fuels, including wood, charcoal, coal for cooking and heating in the residential sector represents one of the largest sources of air pollutant emissions in many communities that lack sufficiently robust electricity and/or gas networks. For these communities it is particularly important in determining the health burden of air pollution as when solid fuels are used for cooking and heating indoors, the resulting household air pollution is associated with elevated exposure to particulate matter, especially for women and children who disproportionately have cooking responsibilities.

The emissions of SLCPs and air pollutants from the combustion of solid fuels is determined by the quantity of the fuel that is combusted as well as by the type and efficiency of technology used in combustion. The International Standards Organisation (ISO) define five levels of standards for cookstoves, with thermal efficiency ranging from <10% to >50%. In many low and middle-income countries, the cookstoves typically used range from three stone fires, through informally produced cookstoves, to commercially produced ones. Many countries lack formal cookstove standards, and the capacity for testing and certification schemes, making the quantification of emissions difficult.

When integrating SLCPs and air pollutants into GHG emission estimates from solid fuel combustion, the Tier 1 approach for quantifying methane and nitrous oxide emissions from biomass fuels is consistent with that applied for SLCPs and air pollutants. The activity variable is the total quantity of fuel (e.g. wood, charcoal) consumed, multiplied by an emission factor. Note that for carbon dioxide, net emissions from biomass consumption is accounted for under Forestry and Other Land Use, as outlined above.

This Tier 1 method can provide a first order approach to quantify SLCP and air pollutant emissions from solid fuel combustion. The EMEP/EEA air pollutant emission inventory guidebook was developed for application in Europe however, and therefore the default emission factors for wood or charcoal combustion are unlikely to reflect the combustion

technologies used in developing countries. In the absence of country-specific emission factors, there are a number of other resources that can be used for default emission factors from biomass combustion in the residential and commercial sectors, including WHO Indoor Air Quality Guidelines, Akagi et al. (2011), Klimont et al. (2017) etc.
As outlined above, the robustness of air pollutant and SLCP emissions from solid fuel combustion in residential and services sectors can be enhanced when information on the specific technologies used with these fuels is known. Information on the efficiency of stoves, or the type of stove used can allow technology-specific emission factors to be applied. There is no comprehensive database of emission factors for all types of stoves. However, there are specific country, and regional studies that provide emission factors which may be appropriate for a particular application.

Other stationary fuel combustion

The residential and commercial sectors may also include combustion of liquid and gaseous fuels, e.g. LPG or natural gas for cooking and/or heating, and in some cases diesel generators for electricity generation. The EMEP/EEA Tier 1 methodologies for quantifying emissions from small-scale combustion of liquids and gaseous fuels is consistent with the methods applied for GHGs in the IPCC guidance. EMEP/EEA includes default emission factors for specific fuels, which can be applied to quantify emissions of SLCPs and air pollutants alongside GHGs using a Tier 1 approach.

The EMEP/EEA Tier 2 approaches for small-scale stationary combustion provides a method that is technology-specific, with default emission factors for some technologies that can be applied to develop a more detailed quantification of emissions.

Key Data Sources to integrate SLCPs and air pollutants

- **EMEP/EEA air pollution emission inventory guidebook for emission factors**
- **Klimont et al. (2017), Akagi et al. (2011) key sources for global emission factors for biomass fuel use**
- **FAO: The Charcoal Transition**

Sector: Manufacturing and Construction Industries

Sub-categories that emit SLCPs and air pollutants:

- **Iron and Steel**
- **Metals**
- **Chemicals**
- **Paper**
- **Food, Beverage and Tobacco**
- **Minerals**
- **Other**

Key considerations on integration of SLCPs and air pollutants into emission assessments

Fuel combustion in the industrial sector emits air pollutants and SLCPs, as well as GHGs. The EMEP/EEA Tier 1 approaches for quantifying these emissions are consistent with the IPCC Tier 1 approaches for GHGs. The fuel consumption is multiplied by fuel-specific emission factors, default values for which are provided in the EMEP/EEA air pollutant emission inventory guidebook. This can provide a first-order estimate of the contribution of different industries to air pollutant emissions.

The technology used in different industries also determines the magnitude of air pollutant and SLCP emissions. If the technologies used in particular industries are known, then the EMEP/EEA Tier 2 approach can be used to quantify the emissions using fuel-, and technology-specific emission factors.

Key Data Sources to integrate SLCPs and air pollutants

- **EMEP/EEA air pollution emission inventory guidebook for emission factors**
- **National pollutant release and transfer registers (PRTR) or regulatory reporting systems for large industry.**

Sector: Electricity Generation

Sub-categories that emit SLCPs and air pollutants:

No further disaggregation

Key considerations on integration of SLCPs and air pollutants into emission assessments

Air pollutant and SLCP emissions are emitted from the combustion of fuels (including fuel oil, diesel, natural gas, and coal, as well as biomass-fired power plants) in the generation of electricity. GHG emissions from electricity generation are determined by the quantity of different fuel that is consumed by different types of power plants. For SLCPs and air pollutants, the installation of end-of-pipe control technologies, such as particulate filters, Flue-gas desulfurization (FGD), low-NO_x burners or Selective Catalytic Reduction (SCR), to reduce emissions of particulate matter, sulphur dioxide, and NO_x emissions respectively, determine the emissions of these pollutants from power generation. Therefore, information about the control technology fitted to power stations is necessary to accurately estimate emissions from electricity generation. The EMEP/EEA Tier 1 approach for power generation for air pollutants and SLCPs is consistent with the IPCC Tier 1 approach. Default fuel-specific emission factors for power generation (e.g. coal, natural gas, heavy fuel oil) can be combined with fuel consumption to estimate SLCP and air pollutant emissions. However, this first-order estimate does not account for the particular control technologies that may be fitted to particular power stations to control air pollutant and SLCP emissions.

The EMEP/EEA Tier 1 approach for power generation for air pollutants and SLCPs is consistent with the IPCC Tier 1 approach. Default fuel-specific emission factors for power generation can be combined with fuel consumption to estimate SLCP and air pollutant emissions. This first-order estimate however, does not account for the particular control technologies that may be fitted to particular power stations to control air pollutant and SLCP emissions.

The EMEP/EEA Tier 2 method provides a disaggregation of electricity generation characteristics by technology type, including default fuel and technology-specific emission factors for different types of power plants. These can be combined with activity data on fuel consumption by technology type to quantify air pollutant and SLCP emissions in further detail.

Key Data Sources to integrate SLCPs and air pollutants

- **EMEP/EEA air pollution emission inventory guidebook for emission factors**
- **Global Power Plant Database**
- **National pollutant release and transfer registers (PRTR) or regulatory reporting systems for large industry.**

Sector: Oil and gas, coal mining fugitive emissions

Sub-categories that emit SLCPs and air pollutants:

- **Coal mining and handling**
- **Oil exploration, processing, distribution and refining**
- **Natural gas venting and flaring**

Key considerations on integration of SLCPs and air pollutants into emission assessments

The previous sections outlined SLCP and air pollutant emission sources from fuel combustion in energy sub-categories. SLCPs and air pollutants can also be emitted through leaks, venting or flaring within fossil fuel production, processing and distribution infrastructure. Fugitive emissions of GHGs from fossil fuel exploration, extraction, processing and distribution include methane emissions leaked, or deliberately vented, as well as carbon dioxide emissions from flaring. Air pollutant emissions emitted alongside these GHGs include a range of non-methane volatile organic compounds. Black carbon, and particulate matter (PM) are also emitted during flaring.

The EMEP/EEA Tier 1 methodologies for quantifying fugitive emissions from oil and gas infrastructure are consistent with the IPCC GHG emission inventory guidance. Default Tier 1 emission factors are provided to quantify fugitive emissions from different processes based on the volume of gas vented or flared, or the volume of product handled through distribution of processing systems/facilities. Higher Tier approaches involve the disaggregation of activity data between specific technologies from which fugitive emissions are emitted.

Key Data Sources to integrate SLCPs and air pollutants

- **EMEP/EEA air pollution emission inventory guidebook for emission factors**
- **Databases on flaring volumes/efficiency**
- **National pollutant release and transfer registers (PRTR) or regulatory reporting systems for large industry.**

Industrial Processes and Product Use

Table A2: Summary of key considerations for quantification of SLCP and air pollutant emissions in IPPU sub-sectors.

Sector: 2.A Minerals

Sub-categories that emit SLCPs and air pollutants:

- **2.A.1 Cement**
- **2.A.2 Lime**
- **2.A.3 Glass**
- **2.A.5.a Quarrying and mining minerals other than coal**
- **2.A.5.b Construction and demolition**
- **2.A.5.c Storage, handling and transport of mineral products**

Key considerations on integration of SLCPs and air pollutants into emission assessments

The primary pollutants emitted from the mineral industry are particulate matter emissions from the dust and other abrasion that takes place during the production processes. Abatement technologies and methods can be utilised to selectively reduce these pollutants, but do not impact CO_2 emissions from the mineral industry. The descriptions outline the key considerations, disaggregated by major mineral industry sub-sector.

Cement production

CO_2 emissions from cement production are determined by calculating the carbonate inputs to production plants because it is the calcination of these inputs that results in CO_2 emissions. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a method for particulate matter. The Tier 1 method only requires the total quantity of clinker produced, which will already be collected for the GHG inventory. The Tier 2 method also requires information on the abatement technologies installed at each plant. The Tier 3 method requires facility-level air emission reports.

Lime production

CO_2 emissions from lime production are determined by calculating the carbonate inputs to production plants because it is the calcination of these inputs that results in CO_2 emissions. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a method for particulate matter. The Tier 1 method only requires the total quantity of lime produced, which will already be collected for the GHG inventory. The Tier 2 emission factors cover two scenarios: uncontrolled kilns where no abatement technology is installed, and controlled kilns where some sort of abatement technology is installed, where method also requires information on the abatement technologies installed at each plant. The Tier 3 method requires facility-level air emission reports.

Glass production

CO_2 emissions from glass production are determined by calculating the carbonate inputs to production plants, understanding the type of glass being produced and the proportion of recycled glass that is used. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a method for many air pollutants including particulate matter, BC and heavy metals. The Tier 1 method only requires the total quantity of glass produced (already collected for the GHG inventory). The Tier 2 method requires disaggregated production data by type of glass. The types are more detailed than those required for GHG inventories, so further investigation may be needed before the Tier 2 emission factors can be applied to production data. The Tier 2 method for particulate matter (and BC) also requires information on abatement techniques. The Tier 3 method requires facility-level air emission reports.

Quarrying and mining minerals other than coal

There are only emissions of particular matter from this sector, so it is not applicable for GHG inventories. The EMEP/EEA Guidebook provides a method for the mining and quarrying of minerals such as rock, sand and gravel that are used to produce aggregate (so does not provide a method for the mining of bauxite, copper ore, iron ore, manganese ore or zinc ore). The Tier 1 method requires national statistics on the quantity of minerals quarried and mined. The Tier 2 method is based on modelling individual processing steps and requires very detailed knowledge about the activities at quarries.

Construction and demolition:

There are only emissions of particular matter from this sector, so it is not applicable for GHG inventories, and would therefore be an additional source if integrated with GHG emissions. The EMEP/EEA Guidebook provides a method for this category. The Tier 1 method requires national statistics on the number of buildings built disaggregated by type of building and the length of newly constructed road. It is likely that these data are not collected for the GHG inventory so will require new data collection processes. The Tier 1 method also requires information on the soil type and climate. A Tier 2 method is not available for this source. The Tier 3 method requires very detailed local data, which is likely to be available only for individual large point sources.

Storage, handling and transport of mineral products:

There are only emissions of particular matter from this sector, so it is not applicable for GHG inventories. The EMEP/EEA Guidebook provides a method for this category. The Tier 1 method assumes that emissions are already estimated in the technical chapters describing the activities. The Tier 2 method requires national statistics on the area used to store minerals and the weight of minerals handled. It does not include EFs for the transportation of minerals. The Tier 3 method requires detailed local/national measurements combined with detailed statistical information.

Key Data Sources to integrate SLCPs and air pollutants

- **EMEP/EEA air pollution emission inventory guidebook for emission factors**
- **National production statistics**
- **Abatement technology information from plants**
- **Facility-level air emission reports**
- **National quarrying and mining statistics**
- **National construction statistics**
- **National pollutant release and transfer registers (PRTR) or regulatory reporting systems for large industry**

Sector: 2.B Chemicals

Sub-categories that emit SLCPs and air pollutants:

- **2.B.1 Ammonia**
- **2.B.2 Nitric acid**
- **2.B.3 Adipic acid**
- **2.B.5 Carbide**
- **2.B.6 Titanium dioxide**
- **2.B.7 Soda ash**
- **2.B.10 Other chemical industry**

Key considerations on integration of SLCPs and air pollutants into emission assessments

Chemical manufacturing can produce a range of different air pollutants from the production processes, in addition to the fuel combustion described above. These emissions occur as by-products from chemical reactions and processing within the chemical production processes. Abatement technologies and methods targeting air pollutants and SLCPs can be utilised but do not impact CO_2 emissions from the industry. The descriptions outline the key considerations, disaggregated by major chemical industry sub-sector.

Ammonia production

CO_2 emissions from ammonia production are determined by using the total fuel requirement along with the carbon content of the fuel. These estimates can be further refined by disaggregating by fuel type and process type. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a method for black carbon, NO_x, CO, NH_3 and NMVOC. The Tier 1 method only requires the total quantity of ammonia produced, which may already be collected for the GHG inventory. The Tier 2 method requires further knowledge of the process: steam reforming or partial oxidation. The Tier 3 method requires facility level data.

Nitric acid production

N_2O emissions from nitric acid production are calculated by using nitric acid production data and technology type. Where available, facility-level monitoring data are used. Abatement technology has a significant impact on emission estimates. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a method for BC and NO_x. The Tier 1 method only requires the total quantity of ammonia produced, which may already be collected for the GHG inventory. The Tier 2 method requires further knowledge of the process type and production data for each. The Tier 3 method requires facility level data.

Adipic acid production

N_2O emissions from adipic acid production are calculated by using adipic acid production data, technology type, and abatement technology type. Where available, facility-level monitoring data are used. Abatement technology has a significant impact on emission estimates. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a method for BC, CO and NO_x. It does not provide a method for $PM_{2.5}$. The Tier 1 and Tier 2 methods only require the total quantity of adipic acid produced, which may already be collected for the GHG inventory. The Tier 3 method requires facility level data.

Carbide production

CO2 and CH4 emissions from silicon carbide and calcium carbide production are calculated using petroleum coke consumption data or carbide production data. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a method for emissions from calcium carbide production of BC and Total Suspended Particulates. The Tier 1 method only requires the total quantity of ammonia produced, which may already be collected for the GHG inventory. The Tier 2 method requires further knowledge of the process type. The Tier 3 method requires facility level data.

Titanium dioxide production

CO2 emissions from titanium dioxide production are calculated using national data on production of titanium slag, synthetic rutile and rutile TiO2 or using plant-level data on quantities of reducing agent and carbothermal input. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a method for BC, NOx, CO, SOx and TSP. The Tier 1 method only requires the total quantity of titanium dioxide produced, which may already be collected for the GHG inventory. The Tier 2 method requires further knowledge of the process type: chloride process or sulphate process.

Soda ash production

CO2 emissions from soda ash production are calculated using data on production of natural soda ash or Trona consumption. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a Tier 1 method for CO, NH3 and TSP. The Tier 1 method only requires the total quantity of soda ash produced, which may already be collected for the GHG inventory. The EMEP/EEA Guidebook does not differentiate between technologies.

Other chemical production

The 2019 EMEP/EEA Guidebook provides a Tier 1 method for NMVOC and TSP emissions from a large group of other chemicals as listed in section 1 in chapter 2.B Chemical industry. There are significant uncertainties with the default emission factors. The 2019 EMEP/EEA Guidebook also provides Tier 2 emission factors for sulphuric acid (SO_x), ammonium sulphate (TSP), ammonium nitrate (NH_3, TSP), ammonium phosphate (TSP, PM_{10}, $PM_{2.5}$), urea (NH_3, TSP, PM_{10}, $PM_{2.5}$, BC), carbon black (NO_x, CO, NMVOC, Sox, TSP, PM_{10}, $PM_{2.5}$, BC), chlorine (Hg), phosphate fertilizers (TSP, PM_{10}, $PM_{2.5}$), ethylene (NMVOC), 1,2 dichloroethane + vinyl chloride (NMVOC), polyethylene (NMVOC, TSP), polyvinylchloride (NMVOC, TSP, PM_{10}, $PM_{2.5}$), polypropylene (NMVOC, TSP), styrene (NMVOC), polystyrene (NMVOC, TSP), styrene butadiene polymers (NMVOC), acrylonitrile butadiene styrene resins (NMVOC), ethylene oxide (NMVOC), formaldehyde (CO, NMVOC, TSP), ethylbenzene (NMVOC), phthalic anhydride (NMVOC), acrylonitrile (NMVOC). This method requires production statistics by technology type. Estimates of particulate can be further refined by understanding the abatement measures implemented at the plants.

Key Data Sources to integrate SLCPs and air pollutants

- **EMEP/EEA air pollution emission inventory guidebook for emission factors**
- **National production statistics**
- **Abatement technology information from plants**
- **Facility-level air emission reports**
- **National pollutant release and transfer registers (PRTR) or regulatory reporting systems for large industry**

Sector: 2.C Metals

Sub-categories that emit SLCPs and air pollutants:

- **2.C.1 Iron and steel production**
- **2.C.2 Ferroalloy production**
- **2.C.3 Aluminium production**
- **2.C.4 Magnesium production**
- **2.C.5 Lead production**
- **2.C.6 Zinc production**
- **2.C.7.a Copper production**
- **2.C.7.b Nickel production**
- **2.C.7.c Other metal production**
- **2.C.7.d Storage, handling and transport of metal products**

Key considerations on integration of SLCPs and air pollutants into emission assessments

Metal production can produce a range of air pollutants from the production processes in addition to the fuel combustion. These emissions occur as by-products from the processes by which metals are converted to usable products. Abatement technologies and methods can be employed to control air pollutants and SLCPs but do not impact CO_2 emissions. The descriptions outline the key considerations, disaggregated by major metal industry sub-sectors.

Iron and steel production

CO_2 and CH_4 emissions from iron and steel production are calculated using production statistics or using a carbon mass balance approach. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a Tier 1 method for 18 pollutants. The Tier 1 method only requires the total quantity of steel produced, which may already be collected for the GHG inventory. The Tier 2 method requires disaggregated data by process type (such as sinter production, pellet production or blast furnace charging) and abatement technologies (such as blast furnaces with heat recovery, fabric filters or dry electrostatic precipitation). Whilst process type may be readily available through the GHG inventory, it is possible that further surveys of facilities will be needed to identify the abatement technologies.

Ferroalloy production

CO_2 and CH_4 emissions from ferroalloy production are calculated using production statistics or using a carbon mass balance approach. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a Tier 1 method for TSP, PM_{10}, $PM_{2.5}$ and BC. The Tier 1 method only requires the total quantity of ferroalloy produced, which may already be collected for the GHG inventory and should be available through national production statistics.

Aluminium production

CO_2 and PFC emissions from primary aluminium production are calculated using production statistics disaggregated by technology time or using anode or paste consumption data. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a Tier 1 method for total aluminium production (i.e. primary and secondary aluminium production). It provides emission factors for 11 pollutants. The Tier 1 method only requires the total quantity of aluminium produced (Readily available from national statistics). The GHG inventory will likely only consider primary aluminium production. The Tier 2 method requires disaggregated data by technology type (such as pre-baked anodes or Søderberg nodes used for primary aluminium production) and includes a range of abatement coefficients that can be used to reflect the particulate matter abatement technologies present at the facilities (such as spray towers, venturi scrubbers, multicyclone and fabric filters). Whilst process type may be readily available through the GHG inventory, it is possible that further surveys of facilities will be needed to identify the abatement technologies.

Lead production:

CO_2 emissions from lead production are calculated using production statistics for each source and furnace type or using a carbon mass balance approach. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a Tier 1 method for total lead production independent of source and furnace type. It provides Tier 1 emission factors for 11 pollutants. It also provides a Tier 2 method for up to 11 pollutants disaggregated by source and furnace type, for which relevant data are likely to be available from the GHG inventory. Abatement coefficients for particulate matter are also available to reflect the abatement technology installed at facilities. Surveys of facilities may be required to obtain this information.

Zinc production

CO_2 emissions from zinc production are calculated using production statistics for each process type or using a carbon mass balance approach. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a Tier 1 method for total zinc production independent of process type. It provides Tier 1 emission factors for 11 pollutants and a Tier 2 method for up to 11 pollutants disaggregated by process type (such as primary or secondary zinc production) and level of abatement. Specific abatement coefficients for particulate matter are also available to reflect the abatement technology installed at facilities. Surveys of facilities may be required to obtain this information. National statistics and the GHG inventory are likely to have production statistics.

Copper, nickel and other metal production

There are no methods for estimating GHG emissions from the production of other metals. For SLCPs and air pollutants, the 2019 EMEP/EEA Guidebook provides a Tier 1 method for copper and nickel production based on total production of the metal. These data should be available from national statistics. The Guidebook also provides a Tier 2 method for copper production by process: primary and secondary production as well as abatement coefficients for particulate matter. Data for copper production by process should be readily available from national statistics. Surveys may be needed to identify abatement technologies installed at facilities.

Storage, handling and transport of metal products

There are only emissions of particular matter from this sector, so it is not applicable for GHG inventories. The EMEP/EEA Guidebook provides a method for this category. The Tier 1 method assumes that emissions are already estimated in the technical chapters describing the activities. The Tier 2 method only provides emission factors for storage of iron ore and requires national statistics on the area used to store the ore and the weight of the ore handled. It does not include EFs for the transportation of minerals.

Key Data Sources to integrate SLCPs and air pollutants

- EMEP/EEA air pollution emission inventory guidebook for emission factors
- National production statistics
- Abatement technology information from plants
- Facility-level air emission reports
- National PRTR or regulatory reporting systems for large industry

Sector: 2.D Solvent use

Sub-categories that emit SLCPs and air pollutants:

- **2.D.3.a Domestic solvent use including fungicides**
- **2.D.3.b Road paving with asphalt**
- **2.D.3.c Asphalt roofing**
- **2.D.3.d Coating applications**
- **2.D.3.e Degreasing**
- **2.D.3.f Dry cleaning**
- **2.D.3.g Chemical products**
- **2.D.3.h Printing**
- **2.D.3.i Other solve and product use**
-

Key considerations on integration of SLCPs and air pollutants into emission assessments

The use of solvents in domestic, commercial and industrial processes emit large volumes of non-methane volatile organic compounds. The IPCC Guidelines references the EMEP/EEA Guidebook when discussing methods to estimate emissions of SLCPs and air pollutants. NMVOC will eventually be oxidised to CO_2 in the atmosphere and these indirect CO_2 inputs can be reported in GHG inventories. These indirect emissions of CO_2 are estimated using the carbon content of the emitted gas.

If indirect CO_2 emissions from the IPPU sector are reported in the GHG inventory, it should be possible to obtain the national NMVOC emissions. If these estimates are not reported, the following sections describe the methods and activity data required to estimate NMVOC emissions from each sub-category.

Domestic solvent use including fungicides

The 2019 EMEP/EEA Guidebook Tier 1 method simply requires national population data to estimate NMVOC emissions. The Tier 2 method requires detailed consumption estimates by technology type (Tier 2a) or solvent type (Tier 2b). These data may be available through national import/export/production statistics depending on their granularity. The data will not be collected for the GHG inventory.

Road paving with asphalt

The 2019 EMEP/EEA Guidebook Tier 1 method requires the annual weight of asphalt used in road paving. The Tier 2 method disaggregates emission factors by purpose of paving (batch mix, drum mix, liquefied asphalt). Emission factors are available for NMVOC, TSP, PM_{10}, $PM_{2.5}$ and BC. Abatement coefficients are presented for particular matter by type of abatement technology.

Asphalt roofing

The 2019 EMEP/EEA Guidebook Tier 1 method requires the annual weight of asphalt roofing produced. The Tier 2 method disaggregates emission factors by technology type. Abatement coefficients are presented for NMVOC and particular matter by type of abatement technology.

Coating applications

The 2019 EMEP/EEA Guidebook Tier 1 method for NMVOC emissions requires the total quantity of paint used by application type (decorative, industrial and other coating). The Tier 2 method requires information on the type of paint, the specific object being painted and the abatement practices in place. This is detailed data that will not be collected for the GHG inventory.

Degreasing

The 2019 EMEP/EEA Guidebook Tier 1 method for NMVOC emissions requires the total quantity of cleaning products used. The Tier 2 method requires disaggregation by process type. Default emission factors are provided for open-top degreasers and electronic components manufacturing. This is detailed data that will not be collected for the GHG inventory, though it is possible that some level of information is available from estimates and data collection made for 2.E Electronics Industry, which includes the use of fluorinated gases to clean electronic equipment during manufacturing.ing.

Dry cleaning

The 2019 EMEP/EEA Guidebook Tier 1 method for NMVOC emissions requires the total quantity of textile treated. These data will not be collected for the GHG inventory. There is also a per capita emission factor available which a very high level of uncertainty. Population data will be readily available. The Tier 2 method requires disaggregation by process type. A default emission factor is provided for open-circuit machines. NMVOC abatement coefficients are available for different abatement technologies.

Chemical products

This category considers NMVOC emissions from polyurethane and polystyrene foam processing; asphalt blowing; tyre production; speciality organic chemical industry; manufacture of paints, inks and glues; fat, edible and non-edible oil extraction; industrial application of adhesives. The 2019 EMEP/EEA Guidebook Tier 1 method is derived from information on products incorporating solvents, polystyrene processing, polyvinylchloride processing and synthetic rubber processing. The required activity data is the total mass of product produced. The Tier 2 method disaggregates data by product. There are default NMVOC emission factors available for 13 products. The activity data required for this category will not be collected for the GHG inventory. NMVOC abatement coefficients are available for different abatement techniques.

Printing

The 2019 EMEP/EEA Guidebook Tier 1 method for NMVOC emissions requires the total quantity of ink consumed by the printing industry. The Tier 2 method requires disaggregation by printing process type: heat set offset, publication gravure, flexography and rotogravure in packaging. NMVOC abatement coefficients are available for different abatement technologies. NMVOC abatement coefficients are available for different abatement techniques. Industry would need to be evaluated to understand whether abatement techniques are being used.

Other solvent and product use

The 2019 EMEP/EEA Guidebook provides default emission factors for a range of other solvent and product uses and a range of pollutants. These include the use of fireworks (14 pollutants), tobacco combustion (17 pollutants), use of shoes (NMVOC), aircraft deicing (NMVOC) and 12 others. Each one requires use-specific activity data such as tonnes of fireworks, tonnes of tobacco, number of pairs of shoes, tonnes of de-icing fluid used. These are all specific datasets that will not be collected by the GHG inventory. NMVOC abatement coefficients are available for different abatement techniques. Industry would need to be evaluated to understand whether abatement techniques are being used.

Key Data Sources to integrate SLCPs and air pollutants

- EMEP/EEA air pollution emission inventory guidebook for emission factors
- National population statistics
- National solvent product statistics
- National production statistics
- National consumption statistics
- Abatement technology information
- Facility-level air emission reports
- National pollutant release and transfer registers (PRTR) or regulatory reporting systems for large industry

Sector: 2.H-2.J Other industry production

Sub-categories that emit SLCPs and air pollutants:

- **2.H.1 Pulp and paper industry**
- **2.H.2 Food and beverages industry**
- **2.I Wood processing**

Key considerations on integration of SLCPs and air pollutants into emission assessments

Other industrial products include process emissions of air pollutants (predominantly non-methane volatile organic compounds) from the paper industry, food and beverages and wood processing. NMVOCs are emitted as a result of the process used to convert raw materials into usable products. These categories are not covered in GHG inventories due to the lack of direct GHG emissions. The sections below summarise the methods and data requirements for each category.

Pulp and paper industry

The 2019 EMEP/EEA Guidebook provides Tier 1 emission factors for eight pollutants and are based on the production of air-dried tonnes of pulp. The Tier 2 emission factors differentiate production by the process and technology: Kraft, acid sulphite process, acid sulphite process with scrubber and electrostatic precipitator. These data are not collected for the GHG inventory.

Food and beverages industry

The 2019 EMEP/EEA Guidebook provides a Tier 1 emission factor for NMVOC and is based on national production data for all relevant food and beverages. The Tier 2 emission factors for NMVOC differentiate between product type and practice such as grain drying for bread and wine, barley malting for beer, production of white bread, coffee roasting and 27 others. The activity data required are production data for each product type and practice. These data are not collected for the GHG inventory.

Wood processing

The 2019 EMEP/EEA Guidebook provides a Tier 1 emission factor for TSP based on the mass of wood products processed. These data may be available through the GHG inventory when considering harvested wood products.

Key Data Sources to integrate SLCPs and air pollutants

- EMEP/EEA air pollution emission inventory guidebook for emission factors
- National production statistics
- Facility-level air emission reports
- National PRTR or regulatory reporting systems for large industry

Sector: 2.K Consumption of POPs and heavy metals

Sub-categories that emit SLCPs and air pollutants:

- **2.K Consumption of POPs and heavy metals**

Key considerations on integration of SLCPs and air pollutants into emission assessments

This category is not covered in GHG inventories. The 2019 EMEP/EEA Guidebook provides a Tier 1 emission factor for Hg and PCB based on population data. These data will be readily available from national statistics.

Key Data Sources to integrate SLCPs and air pollutants

- EMEP/EEA air pollution emission inventory guidebook for emission factors
- National population statistics

Agriculture, Forestry and Other Land Use

Table A3: Summary of key considerations for quantification of SLCP and air pollutant emissions in AFOLU sub-sectors.

Sector: Livestock

Sub-categories that emit SLCPs and air pollutants:

- **Enteric Fermentation**
- **Manure Management**

Key considerations on integration of SLCPs and air pollutants into emission assessments

Livestock production produces SLCP and air pollutant emissions through enteric fermentations and manure management. Ruminant livestock, including cattle, but also sheep, goats and pigs, produce methane during the digestion of their feed through the process of enteric fermentation. Manure also produces emissions during its storage, deposition on pastureland and application on crop or pastureland. Emissions include CH_4, N_2O both directly and indirectly through leaching and volatilisation, and NH_3 and NO emissions. The manure management systems on farms determine the magnitude of these emissions. The key considerations when integrating emission estimates of these pollutants are described below

Enteric fermentation

Methane is the sole SLCP and GHG emitted from enteric fermentation, and the IPCC guidelines provide methodology to estimate this.

Manure Management

Livestock housing and manure management emit the air pollutants NH_3, NO_x, NMVOCs and PM, as well as the GHGs CH_4 and N_2O.

NH_3 and NO_x

There are close synergies between the methods for estimating N_2O emissions and NH_3 and NO_x, with coordination between default parameters provided in IPCC Guidelines and the EMEP/EEA Guidebook. Emissions of all of these nitrogen species depend on the same parameters: number of animals, quantity of nitrogen (N) excreted per animal, and housing and manure management systems (MMS) used.

At Tier 1 level, the number of animals and distribution of manure across different MMS are the only country-specific data required to provide a first-order emissions estimate for air pollutants, using default parameters. The IPCC guidelines has a slightly more detailed Tier 1 equation which explicitly includes animal mass and N excretion rate, whereas the EMEP/EEA guidelines bundles up default animal mass, N excretion rate (for Western Europe), grazing time and emission factors per N excreted into a single per animal emission factor. The EMEP/EEA EFs make use of IPCC defaults when calculating the EF per animal.

The other difference of note is the categorisation of MMS in the EMEP/EEA Guidebook, which provides different EFs for slurry vs. solid manure only (as well as assuming a certain default time spent grazing), compared with around 15 different MMS in the IPCC Guidelines. This requires some aggregation of MMS data into the solid and slurry categories required.

Tier 1 methodology allows a first estimate of emissions, but due to the bundling of different processes into a single EF is not easily able to capture mitigation impacts from reduction in N excretion or changes in housing or manure management practices. In addition, the Tier 1 default EFs may not be very applicable to some countries and may not be consistent with the GHG inventory calculations:

- The use of default Western European values from the IPCC Guidelines for N excretion per animal may not be appropriate for some countries where animal mass, productivity per animal and feed types differ significantly. Regional default value for key parameters such as N excretion rates and animal mass are available from the FAO GLEAM model: https://www.fao.org/gleam/model-description/en/
- Grazing time / fraction of manure deposited whilst grazing assumed by the EMEP/EEA EFs may differ significantly from the true values, and those used in the GHG inventory.

Tier 2 methodology using a nitrogen-flow approach is more flexible, producing more accurate estimates of NH_3 and NO_x emissions (by separating out emissions from housing, yards, storage and application) but also require more input data. In addition to livestock numbers and MMS used, it requires data on N excretion, proportion of ammoniacal N in manure, time spent in housing or outdoors, input of bedding, proportion of manure stored versus spread directly or sent to biogas digesters. Default values are available however, for most of these parameters where required, and N excretion values from GHG inventory calculations can be used as a key input. Tier 2 methodology can capture the impact of some mitigation measures such as feeding strategies to reduce N excretion and increase in grazing time, but in itself does not provide an easy way of quantifying abatement from housing and manure storage measures (e.g. air scrubbing or covering slurry stores). To monitor the impact of these measures Tier 2 emission factors from housing and manure storage need to be modified, based on country-specific data on penetration of different abatement techniques and abatement efficiency.

Where NH_3 and NO_x volatilisation are estimated from manure management (especially when via a Tier 2 method), this can (and should) provide a direct input into estimating the indirect N_2O emissions from atmospheric deposition, replacing the FracGAS parameter in IPCC methodology., Care must be taken when doing so however, to make sure emissions of N_2 and leaching of N compounds in effluent are also taken into account when calculating total N loss. N_2 emissions factors are only provided for Tier 2 methods, and leaching is not quantified in any methods in the EMEP/EEA Guidebook. This is necessary to ensure the correct amount of N remaining in manure applied to soils is available for IPCC N_2O emission calculations.

NMVOC

NMVOC emissions arise from a variety of sources including silage stores, silage feeding, manure in houses, and storage of manure.

For Tier 1, estimates of NMVOC emissions with the EMEP/EEA Guidebook are based on a single EF per animal for all of these sources combined. However, it does also require information on whether silage is part of the diet or not, with different EFs for with and without silage.

As for the NH_3 and NO_x estimates, Tier 1 does not lend itself for capturing the impacts of any mitigation strategies, except for a change in the amount of silage in the diet.

For Tier 2, more accurate estimates can be obtained by considering each source separately. To implement fully, the method requires:

- Data of feed gross energy intake (for cattle) or volatile solid (VS) excretion (for other livestock), which are calculated as part of Tier 2 IPCC livestock characterisation in GHG calculations. Therefore, if Tier 1 (from the 2006 Guidelines) methods are used for the GHG inventory, this method is not possible. However, it is noted that default VS excretion values are provided in the IPCC 2019 Refinement, which could help implementation of this method.
- Data on the fraction of silage in feed (rather than just presence/absence in the Tier 1 method)
- NH_3 emissions estimates for housing, storage and manure application respectively, as this is used as a predictor of comparative NMVOC emissions in these locations. Therefore, Tier 2 NMVOC calculations are dependent on Tier 2 methods being used for NH_3.

Key Data Sources to integrate SLCPs and air pollutants

- EMEP/EEA air pollution emission inventory guidebook for emission factors
- National agricultural statistics
- FAOStat
- UNECE guidance on integrated sustainable nitrogen management

Sector: Crop Production

Sub-categories that emit SLCPs and air pollutants:

- **Synthetic and organic fertiliser application**
- **Manure and dung deposited whilst grazing**
  Standing cultivated crops
- **Pesticide application**
- **On-farm operations (e.g. tillage and harvesting)**

Key considerations on integration of SLCPs and air pollutants into emission assessments

Crop production produces air pollutant emissions through the application of synthetic and organic fertiliser to crop and pastureland. Fertiliser application produces NH_3 and NO emissions alongside N_2O emissions. Non-methane volatile organic compounds are also emitted during crop growth and production. Key considerations when estimating these air pollutant emissions alongside GHG include the following for each sub-category:

Synthetic fertiliser application

Emissions of NH_3 and NO_x occur following application of synthetic fertilisers, and the extent of emissions depend on a variety of factors including fertiliser type, soil properties (especially pH), climate and timing with respect to plant uptake.

In a Tier 1 approach from the EMEP/EEA Guidelines, estimating NH_3 and NO emissions is very simple, as a single emission factor is provided based only on the quantity of N applied to soils, which is also the basis of direct N_2O emissions in Tier 1 IPCC methodology.

However, the Tier 1 default EFs are based on the average mix of fertiliser types used in Europe and central Asia, so have high uncertainty, may not be accurate for a country elsewhere in the world, and cannot account for changes in fertiliser type to mitigate emissions.

A Tier 2 approach provides a range of emission factors for individual fertiliser types, climates and soil pH. Which allows more accurate emission estimates and can account for shifts in the types of fertiliser used. Tier 2 methods do not automatically capture the impacts of other abatement measures (see below), however, and this would require modification of default EFs based on country-specific penetration rates and abatement efficiencies.

Where NH_3 and NO_x volatilisation are estimated from synthetic fertiliser application (especially when via a Tier 2 method), this can (and should) provide a direct input into estimating the indirect N_2O emissions from atmospheric deposition after volatilisation from soils, replacing the FracGASM parameter in IPCC methodology.

Organic fertiliser application and manure and dung deposited whilst grazing:

NH_3 and NO_x are emitted from all types of organic nitrogen-containing amendments applied to soils through volatilisation.

As for synthetic fertilisers, for non-manure organic fertilisers (compost, sewage sludge), Tier 1 emissions factors are provided in the EMEP/EEA Guidebook per kg N applied, so utilise the same activity data as Tier 1 IPCC GHG calculations. This allows a simple first-order to estimate of emissions, but assumes a particular composition or the material applied, so may have high uncertainty.

For livestock manure applied to soil and deposited whilst grazing, Tier 1 emissions estimates are calculated based on per animal emission factors split by livestock type and MMS, rather than quantity of N applied. This is the same activity data required as for NH_3 and NO_x emissions from manure management and should also be available from IPCC GHG calculations as long as these are structured in a way that calculates manure available to apply to land and deposited on pastures from different livestock types and management systems separately (which should be easy to implement). The caveats around use of Tier 1 methodology for livestock manure application are the same as those listed above for Tier 1 manure management estimates.

There is no Tier 2 method for non-manure organic fertilisers. Tier 2 methodology for NH_3 and NO_x emissions from manure applied to soils and deposited whilst grazing is also part of the nitrogen-flow algorithm mentioned above under Tier 2 methodology for emissions from housing and manure management, and therefore requires the same input data. Tier 2 estimates explicitly take into account N excretion per animal and grazing time as well as losses from manure management, but again does not provide an automatic way of accounting for mitigation measures. This must be achieved by modifying EFs according to country-specific penetration and abatement efficiency of measures.

Where NH_3 and NO_x volatilisation are estimated from organic fertiliser application (especially when via a Tier 2 method), this can (and should) provide a direct input into estimating the indirect N_2O emissions from atmospheric deposition after volatilisation from soils, replacing the FracGASM parameter in IPCC methodology.

Standing cultivated crops and on-farm operations:

Emissions of gases (NMVOC, NH_3) from crop canopies and particulate matter from agricultural operations (tillage, crop harvesting, drying) are sources category not covered under IPCC methodology, as no GHGs are produced.

The EMEP/EEA Guidebook contains Tier 1 and Tier 2 methods to estimate these emissions. For Tier 1, both sources require only activity data on the total area agricultural land (for NMVOCs from standing crops) and cropland (for PM from agricultural operations). IPCC GHG calculations already require such data for estimating the quantity of crop residues applied to soils or burned, and for LULUCF calculations, so this should be readily available. However, for both sources the Tier 1 method makes an assumption as to the proportion of land taken up by different crop types and grassland which individually have very different emission characteristics. Therefore, the Tier 1 methods may not accurately represent a given country and will not reflect change over time in shares of different crops.

Tier 2 methods in the EMEP/EEA Guidebooks provide separate default emission factors for a range of common crops and for grass, which requires more detailed data on area and dry matter yield (for NMVOC) of these different crop types. This activity data is also used as part of IPCC GHG calculations though, so can be adapted for use here. Where data from national sources are not available, FAO statistics provide estimates of crop area and yields by crop type.

Pesticide application

Historically a range of different substances were of interest, but since the banning of various substances by international agreement, emissions of HCB are the only ones that need to be reported. HCB occurs as a contaminant in many pesticides.

This source is not linked to GHG emissions, so requires different activity data, namely:
- Estimates of the quantity of different types of pesticides applied.
- Estimate of the “impurity factor” (mass of HCB per kg of pesticide) for each type.

The quantity of pesticides applied may be estimated indirectly from manufacturer’s sales data or imports, or from the results of agricultural surveys. Impurity factors are likely to require requesting information from the manufacturers, or from dedicated chemical analysis.

Key Data Sources to integrate SLCPs and air pollutants

- National agricultural statistics
- EMEP/EEA air pollution emission inventory guidebook for emission factors
- FAOStat:
- Manure management calculations
- UNECE guidance on integrated sustainable nitrogen management

Sector: Biomass burning

Sub-categories that emit SLCPs and air pollutants:

- **Field burning of agricultural residues**
- **Burning of grasslands and savannahs**

Key considerations on integration of SLCPs and air pollutants into emission assessments

Burning of agricultural residues in fields, of grasslands and of savannahs generates a range of air pollutants, including CO, NMVOCs, NOx, SO_2, NH_3, PM and BC, heavy metals (from trace amounts present in biomass) and POPs.

Burning of agricultural residues and grasslands/savannahs is also covered by IPCC methodology. Although CO_2 emissions from burning this biomass are not counted towards national total GHG emissions (it is assumed that all CO_2 released is re-absorbed the next year by regrowth of crops / grass on the same land in the following year)[3], emissions of direct and indirect GHGs including CH_4, N_2O, CO, NMVOC and NO_x are accounted for, and default emission factors provided in Vol4, chapter 2, table 2.5 of the 2006 IPCC Guidelines. This accounts for several of the key air pollutants arising from biomass burning.

Further emission factors (per kg dry matter burned) are provided in the EMEP/EEA 2019 Guidebook. In the Tier 1 approach, a single emission factor is provided for all types of crop residue burned. In the Tier 2 approach, separate emission factors are provided for wheat, barley, maize and rice residues, allowing more accurate estimates for these common crops. Note that the units of emission factors in the IPCC and EMEP/EEA methodologies differ.

The activity data required for calculating emissions of other air pollutants using methodology in the EMEP/EEA 2019 Guidebook is very similar to that required in IPCC methodology.

In both cases, the Tier 1 method requires data on:

- The area of land where residues are burnt
- the quantity per hectare of biomass (dry matter) available for combustion (excluding any residues removed for other purposes)

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[3] Note that where biomass burning results in a net change in biomass that is not reversed the following year (for example, when land is cleared for another purpose through burning), CO2 emissions resulting from this change are accounted for in the LULUCF sector.

- the proportion of biomass available which is actually burned (the combustion factor)

In the 2006 IPCC Guidelines, default values for some crops (wheat, maize, rice and sugarcane) and grassland are provided for the biomass combusted per hectare of burnt land. These could be made use of in emissions calculations for air pollutants, though may not cover all relevant crop types.

Where additional activity data is required for other crop types, national statistics on crop yields and typical dry matter content of residues should be used to estimate quantity of residues available, using the default combustion factors provided in the 2006 IPCC Guidelines (Vol4, Chapter 2, Table 2.6). If national data are not available, crop yield data is also available from FAO statistics, and the quantity of above ground dry matter in residues can be derived from yield data using the methods presented in equation 11.7 and table 11.2 in Chapter 11, Vol4 of the 2006 IPCC Guidelines (which is part of the calculation of N_2O emission from nitrogen added to soil in crop resides).

Key Data Sources to integrate SLCPs and air pollutants

- National agricultural statistics
- EMEP/EEA air pollution emission inventory guidebook for emission factors
- FAOStat for data on on crop yields
- Equation 11.7 and Table 11.2 in the 2006 IPCC Guidelines, Vol4, chapter 11.

Waste

Table A4: Summary of key considerations for quantification of SLCP and air pollutant emissions in waste sub-sectors.

Sector: Solid waste disposal

Sub-categories that emit SLCPs and air pollutants:

- **Solid waste disposal sites (SWDS)**
- **Biological treatment of solid waste**
    - Composting and anaerobic digestion
- **Waste incineration**
- **Open burning of waste**

Key considerations on integration of SLCPs and air pollutants into emission assessments

Disposal and treatment of solid waste results in methane emissions from the decomposition of organic waste under anaerobic conditions. Incineration of waste with fossil carbon content can also result in CO_2 emissions from solid waste disposal. Alongside these GHGs, air pollutants and SLCPs can be emitted through burning of waste, including at waste incineration plans, or open burning at landfills, dumpsites, or in the home. Key considerations when integrating air pollutant emission estimation with GHG emission estimates include:

Solid waste disposal sites

Within existing IPCC guidance, the focus from solid waste disposal sites is on the anaerobic decay of waste in landfills. A first-order decay (FOD) model is used widely by Parties as a robust method for generating a profile of CH_4 from landfills over time. The EMEP/EEA guidance provides simple emission factors for particulates (fugitive particles from waste handling) and NMVOC. These are simple to estimate for Parties that collect annual data on municipal waste collected/arising.

A more complex issue in this category that is poorly defined in emission inventory guidance relates to **landfill fires** that are present either as a management technique, or through accidental/illegal activity. To calculate this impact, GHG inventory compilers would need to develop activity data on the scale of the landfill fire in terms of the material combusted and then ensure that the waste (as dissolved organic carbon – DOC) that is accounted for within the FOD model is reduced where appropriate to avoid a double counting of emissions. These combustion activities at landfill sites are likely to be a large potential source of the main air pollutants and SLCPs, with local or national importance, rather than being of global source significance.

Biological treatment of solid waste

Activity data that is collected to estimate emissions of CH_4 and N_2O from biological waste treatment under IPCC methodologies can also be used to calculate emissions of NH_3 and CO, although these are not emitted in significant amounts.

Waste incineration

Controlled waste incineration at facilities is recorded under IPCC methodologies and accounts only for facilities that do not recover energy. Emissions from facilities with energy recovery are accounted for in the energy sector. As such, this practice is becoming less prevalent for the handling of MSW but may still be important for other waste streams such as clinical or hazardous wastes. Collected activity data for the GHG inventory can easily be used to estimate emissions for a range of air pollutants and SLCPs, using methods and default emission factors outlined in EMEP/EEA (2019).

Open burning of waste

As mentioned above, open burning of waste at landfills or dumpsites should be calculated with care, as linked estimates of methane using FOD models may need to be adjusted for activity data that is combusted rather than being available for anaerobic breakdown.

This category is typically reported in many developing country GHG inventories where local, informal burning of solid waste occurs. Activity data is hard to generate accurately, but may be derived through local studies/surveys, or by making assumptions about the scale and treatment of uncollected MSW, which is more prevalent in rural areas. As with most combustion sources, emissions of air pollutants and SLCPs can be estimated once activity data has been derived. Depending on the type of waste burnt, this activity can be locally and nationally significant as a source of both CO_2 and a whole range of air pollutants.

Reporting of emissions under this category can become politically sensitive. In a number of countries, open burning of MSW is prohibited by law but will often still occur. In countries where this reporting is missing in the GHG inventory, it may be necessary to develop methodologies so that potentially harmful localised emissions of air pollutants are not similarly overlooked.

Flaring

Flaring of emissions under this category can become politically sensitive. In a number of countries, open burning of MSW is prohibited by law but will often still occur. In countries where this reporting is missing in the GHG inventory, it may be necessary to develop methodologies so that potentially harmful localised emissions of air pollutants are not similarly overlooked.

Key Data Sources to integrate SLCPs and air pollutants

- EMEP/EEA air pollution emission inventory guidebook for emission factors
- US AP42
- National studies and research

Sector: Wastewater

Sub-categories that emit SLCPs and air pollutants:

- **Domestic and industrial wastewater treatment and discharge**

Key considerations on integration of SLCPs and air pollutants into emission assessments

The treatment and handling of wastewater can be complex to estimate within GHG inventories. It is a significant source of methane, where treatment measures are initiated to reduce the release of potentially harmful wastewater into natural environments. Methane is the by-product of this intervention where anaerobic measures are implemented at WWTPs. Emissions of N_2O are also accounted due to the role of nitrogen accumulation (from both domestic and industrial sources). The manner of wastewater treatment influences the emissions of nitrogen to air as N_2O and NH_3, which can be introduced by integrating SLCPs and air pollutants into the GHG inventory system. Emissions of NH_3 are not expected to be nationally significant from this source. It will also be possible to estimate emissions of NMVOC from the activity data collected.

Key Data Sources to integrate SLCPs and air pollutants

- EMEP/EEA air pollution emission inventory guidebook for emission factors
- US AP42

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