GUIDE TO ASSESSING THE COSTS OF INACTION OF TACKLING AIR POLLUTION

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UN environment programme

This Guide was developed as part of the 2021-2023 United Nations Environment Programme project 'Strengthening ASEAN Member State Policies with Environmental Health Data on Costs of Inaction and Co-Benefits'. This project was funded by the United Nations Development Account.

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Available at: [link to publication]

First published in May 2023.

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ACKNOWLEDGEMENTS

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ACRONYMS

ALRIs	Acute Lower Respiratory Infections
ASEAN	Association of Southeast Asian Nations
BC	Black Carbon
BenMAP-CE	Environmental Benefits Mapping and Analysis Program - Community Edition
BRT	Bus Rapid Transit
CGE	Computable General Equilibrium
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COPD	Chronic Obstructive Pulmonary Disorder
CTM	Chemical Transport Model
EDGAR	Electronic Data Gathering, Analysis, and Retrieval
EMEP/EEA	European Monitoring and Evaluation Programme/European Environment Agency
GAINS	Greenhouse Gas – Air Pollution Interactions and Synergies
GBD	Global Burden of Disease
GDP	Gross Domestic Product
GEOS	Goddard Earth Observing System
GHG	Greenhouse Gas
GIS	Geographic Information System
GISS	Goddard Institute for Space Studies
HFC	Hydrofluorocarbons
IBC	Integrated Benefits Calculator
IPCC	Intergovernmental Panel on Climate Change
LEAP	Low Emissions Analysis Platform
LPG	Liquefied Petroleum Gas
MoNRE	Ministry of Natural Resources and Environment
NDCs	Nationally Determined Contributions
NGOs	Non-Governmental Organizations
NH_3	Ammonia
NO_x	Nitrogen Oxides
O_3	Tropospheric Ozone
O&M	Operation and Maintenance
OECD	Organization for Economic Co-operation and Development
PM	Particulate Matter
QALY	Quality-adjusted Life Year
RFM	Reduced Form Model
SCC	Social Cost of Carbon
SDGs	Sustainable Development Goals
SLCPs	Short-lived Climate Pollutants
SO_2	Sulphur Dioxide
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VOC	(non-methane) Volatile Organic Compounds
VSL	Value of a Statistical Life
WHO	World Health Organization
WTP	Willingness-To-Pay

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EXECUTIVE SUMMARY

ASEAN countries have had some success in reducing air pollution over the last few decades, however, air pollution remains a significant issue. A recent assessment of air pollution in ASEAN showed that even if current policies are successfully implemented, air pollution and its impacts will increase into the future. There are multiple negative impacts of air pollution, including for health, climate change, as well as for other environmental issues such as water or soil pollution and biodiversity loss. These impacts will also have negative costs to the economies of ASEAN countries.

Methodology exists for quantifying the economic costs of several impacts, including but not limited to the costs associated with the health impacts of air pollution exposure, as well as other environmental and societal costs associated with climate change or biodiversity loss. Bringing in additional policies which tackle air pollution further across ASEAN countries will reduce the impacts of air pollution and also its associated costs. This will have multiple benefits for health, the environment, the economy and society at large and could also help countries achieve other development priorities such as those aligned with the Sustainable Development Goals.

There are often barriers which hold back further action, including delayed and ineffective implementation, financing shortfalls, coordination challenges, capacity gaps and inefficient regulation. Through quantifying the differential costs of impacts in two alternative scenarios (outlined in the Fig.ES1 below), the concept of the 'cost of inaction', defined here as forgone benefits of not adequately addressing air quality, can provide further evidence to motivate and stimulate action on air pollution.

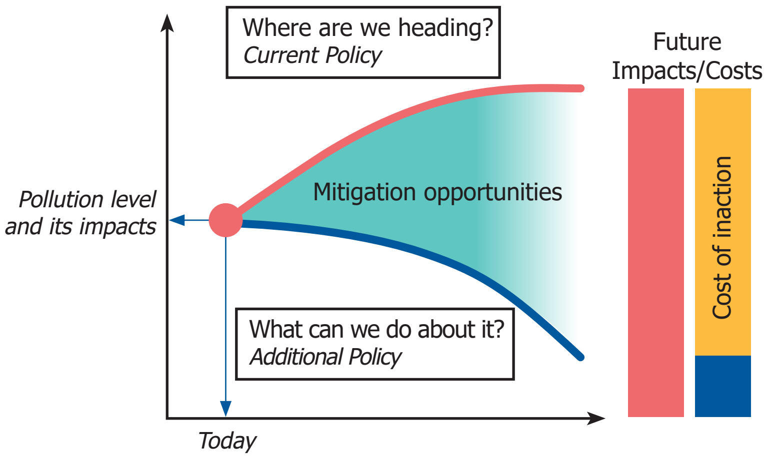


Fig. ES1: *Schematic detailing how air pollution levels and impacts can change into the future under different policy scenarios and detailing the concept of the cost of inaction as the difference in impact costs in two alternative future scenarios.*

This document provides detailed guidelines for an assessment team to undertake a cost of inaction assessment based on rigorous scientific methods and best available data. Such assessment would include quantification of pollutant emissions, concentrations, impacts and costs for alternative future scenarios with differential levels of air pollution (see Fig.ES1 above). It also provides examples of good practices in the ASEAN region which should be built upon throughout the assessment process to ensure the assessment is robust and can be communicated and utilized effectively. Following these guidelines and good practices, ASEAN countries can develop and utilize cost of inaction assessments to overcome current barriers and motivate action on air pollution.

1. Introduction

Despite recent efforts to reduce emissions, air pollution is still a significant global health issue. The Global Burden of Disease (GBD) study classified exposure to air pollution as the fourth leading risk factor for premature mortality, resulting in almost 6.7 million premature deaths globally in 2019. In the 10 member states of the Association of Southeast Asian Nations (ASEAN) region, exposure to air pollution also poses a significant health burden, resulting in almost half a million deaths in 2019 (Institute for Health Metrics and Evaluation [IHME], 2020). Reducing the health impacts of air pollution is a direct target of one of the Sustainable Development Goals (SDGs). Alongside the clearly identified health benefits, there are also multiple other co-benefits that can be potentially achieved from implementing policies to mitigate air pollution. These include benefits for climate change mitigation and the environment as well as substantial social and economic co-benefits including improved economic productivity, enhanced quality of life and reduced poverty. In recognition of this, the right to a Clean and Healthy Environment, including the right to Clean Air, was recently enshrined as a human right by the United Nations (United Nations General Assembly, 2022).

Often, one of the highest barriers for vigorous policy action on air pollution is the direct investment and indirect costs that are required to implement new measures, including perceived negative impacts on the economy. However, there are various direct and indirect costs associated with air pollution that will remain if new action is not taken. At the same time, implementing new measures to reduce air pollution could also result in multiple co-benefits, some of which will have a positive economic impact. In many cases, these costs and foregone benefits –the 'costs of inaction' - are likely to be higher than the costs related to introducing a new measure (or the 'costs of action'). Quantifying and communicating the 'costs of inaction' relating to air pollution can offer positive arguments for cost-effective emission control policies by framing policy inaction as undesirable, and action as positive.

This document aims to provide an overview of the potential for cost of inaction assessments to be used in the ASEAN region, as well as presenting practical guidance for undertaking a cost of inaction study relating to air pollution. The document is set out as follows: Section 2 provides a background to the challenges of air pollution in ASEAN, introduces the concept of cost of inaction and details how cost of inaction assessments could be used to help overcome some of these challenges. This section is targeted at working-level policymakers and stakeholders across multiple governmental agencies (e.g. environment, health, education, energy, agriculture, finance, etc.), as well as Non-Governmental Organizations (NGOs) and advocacy groups or anyone interested in learning more about cost of inaction assessments. Section 3 provides detailed practical guidance on how to develop cost of inaction assessments, including data requirements, available modelling tools and capacity requirements and is targeted primarily towards technical experts who might be undertaking a cost of inaction assessment. Finally, section 4 identifies some challenges that an assessment team may face and the opportunities from undertaking a cost of inaction assessment which could help to overcome these. It also presents some recommendations and recommended next steps once initial cost of inaction assessments have been developed.

2. Taking a Costs of Inaction Approach

2.1.The Challenge

2.1.1. State of Air Pollution Impacts in ASEAN

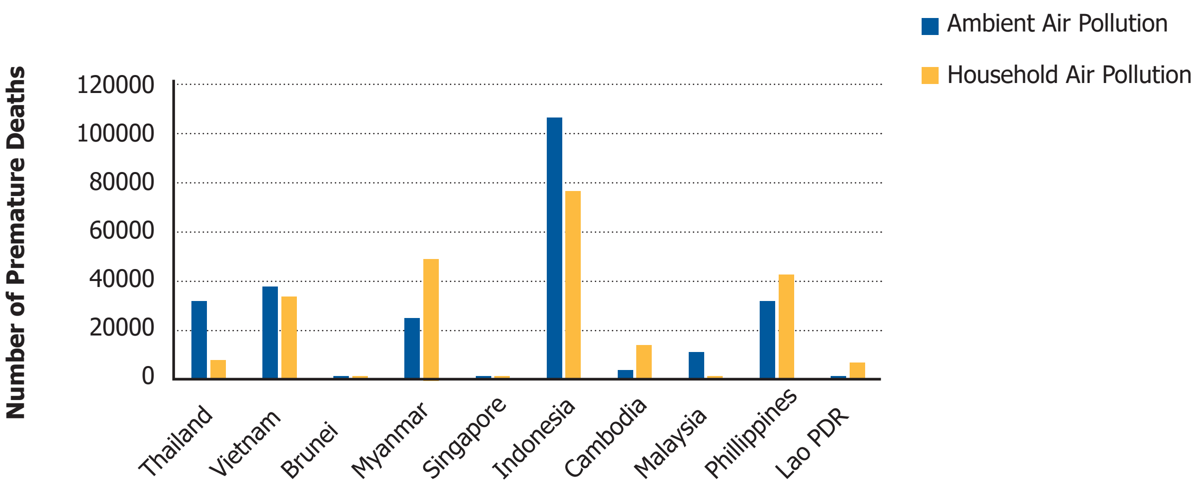


Fig. 2.1 *Estimated total number of premature deaths for both genders and all age groups due to exposure to ambient (blue bars) and household (yellow bars) air pollution exposure in all ten ASEAN member countries according to the most recent GBD estimates (IHME, 2020)*

Rapid economic development over the last few decades has resulted in improved health and wellbeing for many of the 665 million people residing in the ASEAN region. However, air pollution remains a significant problem. In 2015, over 85% of people in ASEAN were estimated to be exposed to levels of ambient fine particulate matter ($PM_{2.5}$) higher than the World Health Organization (WHO)'s 2021 recommended guidelines of 5 µg/m³ for the protection of human health, while over 15% were also estimated to be exposed to concentrations higher than the WHO's Interim Target 1 of 35 µg/m³ (UNEP/CCAC, 2023). As Fig 2.1 indicates, exposure to $PM_{2.5}$ results in premature death across the ASEAN region, including due to increased risks of stroke, heart disease, type 2 diabetes, lung cancer, chronic obstructive pulmonary disorder (COPD), acute lower respiratory infections (ALRIs) and low birth weight. The GBD study directly quantifies the increased risk of these health end points due to exposure to ambient $PM_{2.5}$, which was estimated to result in 250 thousand premature deaths in ASEAN in 2019, while a further 230 thousand premature deaths were associated with exposure to household air pollution (IHME,2020). Importantly, premature deaths represent the peak of the health impact pyramid and there are several causal relationships which have been identified in literature but where methodology for quantifying the attributable burden has not yet been developed. For example, air pollution can be a key risk factor in the exacerbation and onset of asthma, pregnancy loss and of developing neurogenerative diseases such as Parkinson's and Alzheimer's (Shi et al., 2020).

The health impacts due to air pollution exposure also have a large cost to the economy. The cost of premature mortality can be calculated by quantifying the 'value of a statistical life (VSL)', while there are also other specific costs from morbidity related to air pollution such as the costs to healthcare services, as well as for people having to take time off work due to sickness and due to lost productivity. The World Bank estimated that the total global economic loss due to the health impacts of air pollution exposure were 8.1 trillion USD or 6.1 percent of global Gross Domestic Product (GDP) in 2019. This cost is not shared equally across the globe, with the health impacts from air pollution estimated to result in a GDP loss of 9.3% in the East Asia and Pacific region compared to 1.7% of GDP loss in North America (World Bank, 2021). As populations are ageing, urbanization is increasing and economies are developing, the health burden of air pollution and consequently the economic costs of air pollution, will continue to increase if no further action on air pollution is taken. Globally, the Organization for Economic Co-operation and Development (OECD) estimates that, by 2060, the global economic costs due to air pollution exposure could reach between 18 and 25 trillion USD (United Nations Environment Programme [UNEP], 2021).

Aside from the direct health impacts caused by air pollution exposure, there are multiple other direct and indirect costs of air pollution. Some air pollutants such as black carbon (BC) and methane (CH_4) are also short-lived climate pollutants (SLCPs) and contribute directly to both air pollution and climate change. Air pollution and greenhouse gas (GHG) emissions often have similar sources and several studies have shown the co-benefits for climate change from acting on air pollution and vice versa (Haines et al., 2017).This means that measures and policies which tackle air pollution could potentially reduce some of the negative effects of climate change, of which countries in the ASEAN region are extremely vulnerable and which also have significant economic costs (Box 1: Costs of Climate Change in ASEAN). Consequently, directly considering the issues of air pollution and climate change in an integrated way could result in enhanced ambition without additional costs or effort.

Aside from those for health and climate change, there are multiple other direct negative impacts of air pollution. Tropospheric ozone (O_3) is known to negatively impact crop yield as well as reducing plant growth and affecting the diversity of plant communities, with negative impacts for biodiversity. While emissions of other air pollutants such as ammonia (NH_3), nitrogen oxides (NO_x) and sulphur dioxide (SO_2) directly contribute to acid rain, and soil and water pollution. In addition to this, there are multiple societal costs due to air pollution, such as reduced tourism, less liveable conditions and reduced economic competitiveness (World Bank, 2021). The multiple costs which are currently felt and will continue to be felt if there is no additional action to mitigate pollution extend even further than the direct impacts highlighted above. For example, the implementation of policies to tackle air pollution could have a positive impact for sustainable development and consequently not implementing such policies could result in a missed opportunity in relation to societal benefits or achieving the SDGs. An example of the multiple co-benefits for acting on air pollution through measures related to clean cooking are highlighted in Box 2.

Box 1: Costs of climate change in ASEAN

Myanmar, Thailand and the Philippines all ranked among the top 10 countries most impacted by climate change globally between 2000 and 2019. In Myanmar alone, which ranked second in the most impacted countries, climate change was estimated to account for an average of 7 thousand deaths and over 1.5 billion USD of economic losses per year over the ten-year period (Eckstein, Kunzel and Schafer, 2021).

Box 2: SDG benefits from clean cooking measures

Reduce air pollution exposure with direct benefits for health

Provide access to clean, reliable and affordable energy

Reduce the time burden on women and girls from cooking and collecting wood fuel

Reduce deforestation through reducing levels of forest removed for fuel wood with benefits for climate and biodiversity

2.1.2. Current Progress and Mechanisms

Many countries in ASEAN have developed specific policies or processes to reduce and monitor progress on reducing air pollution. As of 2020, more than 60% of countries in the Asia and Pacific region had ambient air quality standards embedded in legislation, while over 55% of countries also had national air quality management strategies or action plans (UNEP, 2021). There are several initiatives within the ASEAN region, at both the national and regional scale which have been developed with the aim of tackling the issues of both air pollution and climate change. These include regional scale assessments and initiatives. The 'Air Pollution in Asia and the Pacific: Science-based Solutions' report, identifies 25 cost-effective clean air measures which if implemented could simultaneously tackle the issues of air pollution and climate change in the Asia and Pacific region while it is also helping countries achieve the SDGs (Amann et al., 2019). The ASEAN State of Climate Change Report (2021) also details the actions that ASEAN members should take to achieve the ASEAN climate vision 2050 (Association of Southeast Asian Nations [ASEAN], 2021). At the national scale, all countries in the ASEAN region have now submitted Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) which details how they plan to reduce GHG emissions.

Some of these policies and strategies relating to both air pollution and climate change, in combination with technological advances and other sector specific plans, have already been successful in improving air quality in ASEAN. Population weighted $PM_{2.5}$ concentrations have decreased, for example, in all countries over the last few decades. This includes reductions between 22% and 29% for Thailand, Cambodia and Indonesia since 1990. This is largely due to the success of policies aimed at reducing air pollution, as well as technological advances and increased energy efficiency in some sectors. Most countries in the ASEAN region have also begun to address the problem of cooking with solid fuels. For example, in Thailand solid fuel use for cooking has reduced by two thirds from 64% in 1990 to 21% in 2019, and in Vietnam by three quarters from 89% to 41% during the same timeframe (State of Global Air, 2020). This has resulted in a large reduction in the health burden from household air pollution across the region, with additional benefits for women, children, and other vulnerable groups, who are often those most exposed to household air pollution exposure (IHME, 2020). Significantly, these decreases in $PM_{2.5}$ concentrations have occurred during a time when GDP in ASEAN has increased by about six times, showing some success by ASEAN countries in decoupling levels of air pollution from economic development.

Understanding the scale and sources of air pollution is a key aspect in the development of air quality management strategies. If this data is available over long timescales, it can also be used as an indicator to measure the effectiveness of policies in improving air quality. This information can be gathered from air quality monitoring networks and measurement campaigns or through the development of sector specific air pollution emission inventories. A lack of air quality monitoring data is often a key issue in air quality management. Within Asia and the Pacific, around 60% of countries have official air quality monitoring networks, but the data is often not spatially diverse enough to understand the full spectrum of sources and levels of exposure (UNEP, 2021). Air pollution emission inventories and mitigation assessments can be used both to complement measurement data and to fill gaps where data is not available or not available at an appropriate spatial or temporal scale. Through directly quantifying the key sources of emissions, emission inventories can allow for better understanding of the spatial distribution and major sources of air pollution at the regional, national, and subnational scale. While mitigation assessments can quantify the emission reduction potential of specific measures, and the potential impact of such measures for improving air quality, reducing the health burden of air pollution and for various other co-benefits such as for climate change. Conducting an emissions inventory followed by a mitigation assessment can lead to the comparison of emission reduction potential, costs of implementation and potential impact for multiple alternative future scenarios. These types of analysis can be useful in the development of policies through supporting the prioritization or development of new mitigation measures or strategies. An example of where mitigation assessments have directly been used to inform policy making is in the development of Cambodia's 2021 Clean Air Plan (Box 3).

Box 3: Using the LEAP tool to develop an air pollution mitigation assessment to feed into Cambodia's clean air plan

The Clean Air Plan of Cambodia, published in November 2021, outlines a set of policies and measures to reduce the emissions of air pollutants. To facilitate the development of the Clean Air Plan, researchers from the Stockholm Environment Institute supported the Ministry of Natural Resources and Environment (MoNRE) in Cambodia in the development of an air pollution mitigation assessment using the LEAP tool (cf Box 7 on Available Tools). This process involved working with stakeholders to collecting key activity data to quantify emissions from all key source sectors, both for a historic period and for a future 'baseline' scenario, assuming no new policies are implemented. This scenario was then used as a baseline to quantify the emission reduction potential of 14 specific clean air measures to reduce air pollutant and GHG emissions, based on inputs from various stakeholders. It was estimated that the implementation of all 14 measures would result in 900 avoided premature deaths per year by 2030 through reduced exposure to air pollution (Cambodia, MoNRE, 2021).

2.1.3. Challenges for Action

While many ASEAN countries are taking action on air pollution, continued population growth, urbanization and economic development will likely offset reductions and lead to additional future air pollution exposure across the region (UNEP/CCAC, 2023). It is important therefore to not only explore the implications of current policies, but also the opportunities for further mitigation. However, there are multiple barriers and challenges that make further action difficult.

Firstly, at the institutional level, there is often a lack of coordination between different stakeholder groups, low levels of awareness for who is responsible for the implementation of measures, and a lack of regional coordination. While the impacts of air pollution - and the measures to mitigate it - cover multiple sectors and issues, air pollution is often treated as an environmental issue and responsibility for reducing air pollution often falls solely on ministries of environment.

Secondly, - and especially in lower income or lower-middle income countries - there is often a lack of capacity and available data to develop coordinated and integrated policies and action plans. For example, to identify actions that can maximise multiple benefits, policy makers require quantitative information about the sources of air pollution, which mitigation options could have the largest impact in reducing emissions, the benefits that can accrue from implementing these, and the costs of action to be taken and the cost of inaction if they are not. Due to the complexities in the relationships between emissions and benefits of action – especially for human health - detailed tools and models often need to be used for developing air quality management strategies and to provide the evidence that supports investment in the actions to reduce emissions from different sectors. The challenge for developing such assessments can therefore be in the lack of capacity and prior knowledge that local teams may have in these areas. A recent UNEP survey among stakeholders in ASEAN countries has confirmed a lack of awareness, limited capacity, and lack of familiarity with relevant tools.

Finally, another key barrier to the implementation of ambitious air quality regulation can be a lack of funding. Air pollution mitigation efforts require sustained investment and commitment. However limited financial resources and budgetary constraints coupled with a lack of political will and suitable financing mechanisms, means that they remain underfunded. A study by the Clean Air Fund (2022) found that just 0.5% of international development funding, or 11 billion USD during the period of 2015 and 2022, went towards improving outdoor air quality (Clean Air Fund, 2022). The same study noted the missed opportunity to finance air pollution mitigation as part of climate action – finding that just 2% of the international development funding allocated to achieving the goals of the Paris Agreement explicitly tackles air pollution.

The following section (2.2) details the concept of the cost of inaction and how it can be used to support the prioritization and development of new mitigation measures and help address some of the challenges that hold back further action on air pollution.

2.2. The Cost of Inaction to Help Develop New Solutions

2.2.1. Definition of the Cost of Inaction

The "Cost of Inaction" refers to the total negative consequences or losses that result from failing to act or make a decision in a particular situation. It encompasses the expenses, damages, or missed opportunities that might result from not acting, as well as any indirect effects. Put simply, it is the cost of not doing anything. The concept of the cost of inaction addresses the misconception that mitigation is associated with high costs and offers positive arguments for cost-effective emission control policies at the national level. It allows for a more comprehensive and balanced accounting of the advantages and disadvantages of policy actions. Building on insights from the psychology of loss aversion this concept is also a rhetorical device that frames policy inaction generally as undesirable, and action as positive (Homar & Cvelbar, 2021).

It may be worth noting, that the conceptual scope of the cost of inaction used in this guide differs slightly from definitions used elsewhere. For example, the OECD defines the cost of inaction as the full monetized impacts of the future 'current policy' or 'business as usual' scenario (OECD, 2008). This definition assumes that all costs from air pollution in a future scenario could be eliminated. In contrast, in this document the cost of inaction quantifies the potentially foregone benefits of alternative future measures or policy intervention. This approach therefore accepts that future policies will not manage to completely eliminate the costs associated with the baseline scenario (i.e. that air pollution will be 100% reduced). The advantage of the approach introduced in this document is that the focus is on the assessment of specific potential policy measures and their associated costs.

The concept of the cost of inaction defined here is illustrated in more detail in Fig. 2.2, specifically in the context of air pollution. Fig. 2.2 shows how the cost of action is the difference in economic costs associated with implementing additional measures related to reducing emissions in the 'additional policies' scenario compared to the 'current policies' scenario (difference in the yellow bars), while the 'cost of inaction' is the total economic cost associated with the differential impacts (difference between the green bars) from reducing emissions (difference in blue bars) in two alternative scenarios: a 'Current Policy' Scenario in which only existing relevant current policies are implemented, and an action or 'Additional Policy' Scenario that reflects the implementation of additional measures as a result of a new policy or set of policies.

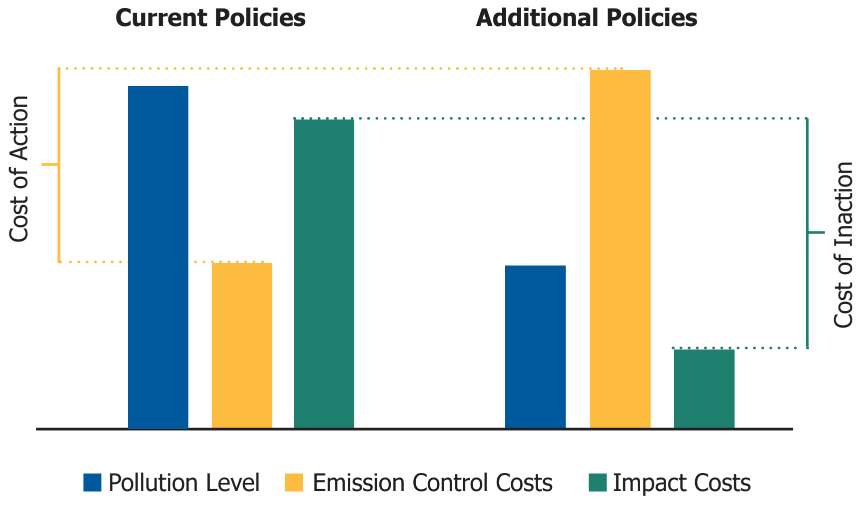


Fig. 2.2 *Schematic picture of the proposed approach for quantifying costs of action vs costs of inaction, relying on the comparison of current policies and additional policies*

For both scenarios, there will be a certain level of ambient air pollution (symbolized by the blue bar in above Fig. 2.2), and costs for implementation of pollution legislation (difference in the yellow bars), and a certain level of health burden (and other environmental and potential social burdens) from air pollution, which is here expressed in monetary terms. In different scenarios, both the associated cost of action and the cost of inaction will be different, depending on which mitigation measures are being included. Furthermore, the magnitude of the associated cost of inaction will also depend on the number of impacts that are quantified in the assessment (e.g. mortality and morbidity impacts of air pollution, climatic impacts and other societal impacts). The broader the set of negative impacts that can be avoided by implementing mitigation measures, and the higher the monetized value of the negative impacts, the higher the overall cost of inaction. If both the cost of action and cost of inaction are quantified, these could then be also used to calculate what we define here as the 'net cost of inaction,' which is the net difference between the cost of action and cost of inaction. This would provide further evidence for the overall costs (or benefits) from acting on air pollution, considering the associated costs from implementing the mitigation measures.

2.2.2. Examples of some Costs of Inaction

The cost of inaction can cover a broad range of indicators, and as highlighted above, the more impacts or indicators which are quantified, the larger the cost of inaction is likely to be. The focus of this Guide is mainly on assessing health costs from air pollution, but many policy actions have multiple impacts that go far beyond health. For example, the introduction of a bus rapid transit (BRT) system in a city will bring about a reduction in air pollution, which will have positive impacts for human health, as well as a reduction in the emissions of GHGs. However, it will also alleviate congestion, which will have its own related costs to health, the economy and well-being. All of these benefits – and many more – will be missed if the BRT is not introduced and can therefore be seen as costs of inaction and compared to the costs of action. Another example for promoting walking and cycling in the transport sector is illustrated in Box 4.

There is a growing literature on the concept of the cost of inaction applied to environmental issues such as air pollution and climate change (United Nations Economic Commission for Europe [UNECE], 2022), though still relatively little is focussed on ASEAN countries. In addition, while several studies quantify and assess the costs of inaction, there is currently no guidance available on how to actually conduct such an assessment. The aim of this document is to give practical guidance on developing a cost of inaction assessment, including the key steps

Box 4: The costs of not promoting walking

Promoting walking through building safe routes, with pavements separated from traffic and with safe pedestrian crossings, would result in a number of different benefits:

involved in the assessment process, good practices which should be followed and end uses of such assessments. While this is currently limited in the quantitative sense to the costs from the health impacts of air pollution, it also aims to strengthen awareness and understanding of:

- the cost of air pollution to society;
- existing mitigation options;
- benefits of actions including co-benefits;
- the availability and capacity of tools to support respective assessments;
- necessary institutional and technical capacity to collect data, perform assessments and engage in science to policy dialogue.

As part of this project on cost of inaction, initial cost of inaction assessments for three ASEAN countries have been developed. An example for Thailand is shown in Box 5. The following section (3) details practical guidance for assessment teams wishing to undertake cost of inaction assessments and good practices which should be followed while doing so.

Box 5: Developing a cost of inaction assessment in Thailand

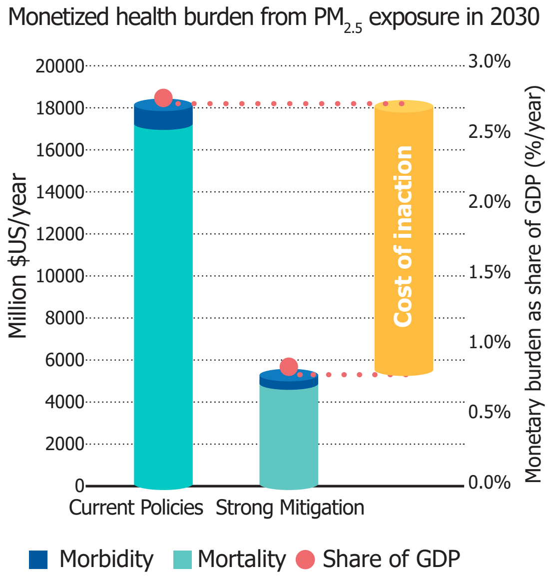


Fig 2.3: *Monetized health burden from $PM_{2.5}$ exposure in 2030, comparing the Current Policies scenario, and effective implementation of all measures considered (Strong Mitigation scenario)*

The GAINS model is a modelling tool which has been used in multiple studies to quantify the benefits of air pollution mitigation measures (See Box 8). As part of the project under which this guide has been developed, the GAINS model was applied to develop an initial assessment of the cost of inaction for Cambodia, Thailand and Indonesia for the year 2030. Within these assessments, the baseline and illustrative policy scenarios follow those which have already been developed within the UNEP-CCAC Assessment on Air Pollution in Asia And the Pacific (Amann et al., 2019), and the UNEP-CCAC Assessment for the ASEAN region (UNEP/CCAC, 2023). For Thailand, the cost of inaction assessment directly quantified the mortality and morbidity costs related to air pollution exposure for six different causes of death (COPD; Ischemic heart disease; Stroke; Lung cancer; ALRIs; Type 2 diabetes) and four morbidity indicators (Asthma-related emergency room visits; Cardiovascular hospital admissions (pre/post 65 years); Respiratory hospital admissions; Respiratory restricted activity days (working age)) in both a baseline scenario, and for a mitigation scenario which includes the implementation of 12 individual mitigation measures. Above figure shows the monetised health burden associated with $PM_{2.5}$ exposure for the baseline (Current Policies) scenario and the action (Strong Mitigation) scenario for Thailand in 2030. The cost of inaction for not implementing the measures in the strong mitigation scenario is therefore the difference between these two alternative scenarios and is estimated at around 12 billion USD per year by 2030.

2.2.3. End Uses of Cost of Inaction Assessments

Developing a cost of inaction assessment also provides an opportunity to strengthen existing or future policies, strategies, and plans, which could benefit from the evidence generated through cost of inaction assessments. Examples of where there is an opportunity to use costs of inaction assessments in policy include but are not restricted to:

- **Clean air action plans.** The cost of inaction assessment could help planners to identify those emission reduction measures that deliver the highest benefits to society, and to propose effective and eventually also cost-effective strategies to deliver these benefits. As Box 3 illustrates, assessing the benefits of different mitigation options helped to identify measures in Cambodia that would have the largest impact. A cost of inaction assessment would also help to strengthen the public messaging of these available measures by indicating all the costs that would be avoided if these measures were taken.
- **NDCs.** There is substantial overlap between the sources of air pollution and GHGs, and consequently NDC measures which aim to reduce GHG emissions will also likely have air pollution benefits. Thus, NDCs can be further motivated and supported by performing cost of inaction assessments for the corresponding measures. This will provide further evidence and support for the implementation of such measures as it is likely that the mitigation costs will be offset by considering the costs of inaction that can be avoided by the mitigation measure.
- **National health plans.** There is large overlap between clean air policies and plans to improve public health, for example strategies to tackle non-communicable diseases. Public health authorities can be expected to be interested in cost of inaction estimates, since much of the costs of inaction accrues in public health systems. Public health authorities are also useful partners in the assessment as they can provide important input data to the analysis.
- **Gender strategies.** Across the ASEAN region, gender is increasingly integrated into environmental policies and plans (see Box 6). With air pollution impacting men and women in different ways, costs of inaction assessments can be used to provide new evidence on how air pollution mitigation can potentially contribute to gender equality and social inclusion.

Box 6: ASEAN Strategic Framework on Gender Mainstreaming

The ASEAN secretariat has developed a 'Gender Mainstreaming Strategic Framework 2021–2025', which highlights multiple ways to improve the inclusion of gender throughout policies, plans and development priorities. Including enhancing capacity for member states to collect gender disaggregated data, and monitoring the impact of policies and plans for men and women.

3. Assessing the Costs of Inaction

3.1. Framework for assessing costs of inaction.

We now turn to the framework that can be used to assess the cost of inaction. This framework proceeds in six phases which are shown in Fig. 3.1 and are described in more detail below. The six phases are listed as follows.

1. Scoping of the assessment: co-designing the assessment with stakeholders
2. Base year validation
3. Baseline scenario development and assessment
4. Alternative policy scenario development and assessment
5. Establishment of differences in costs and impacts

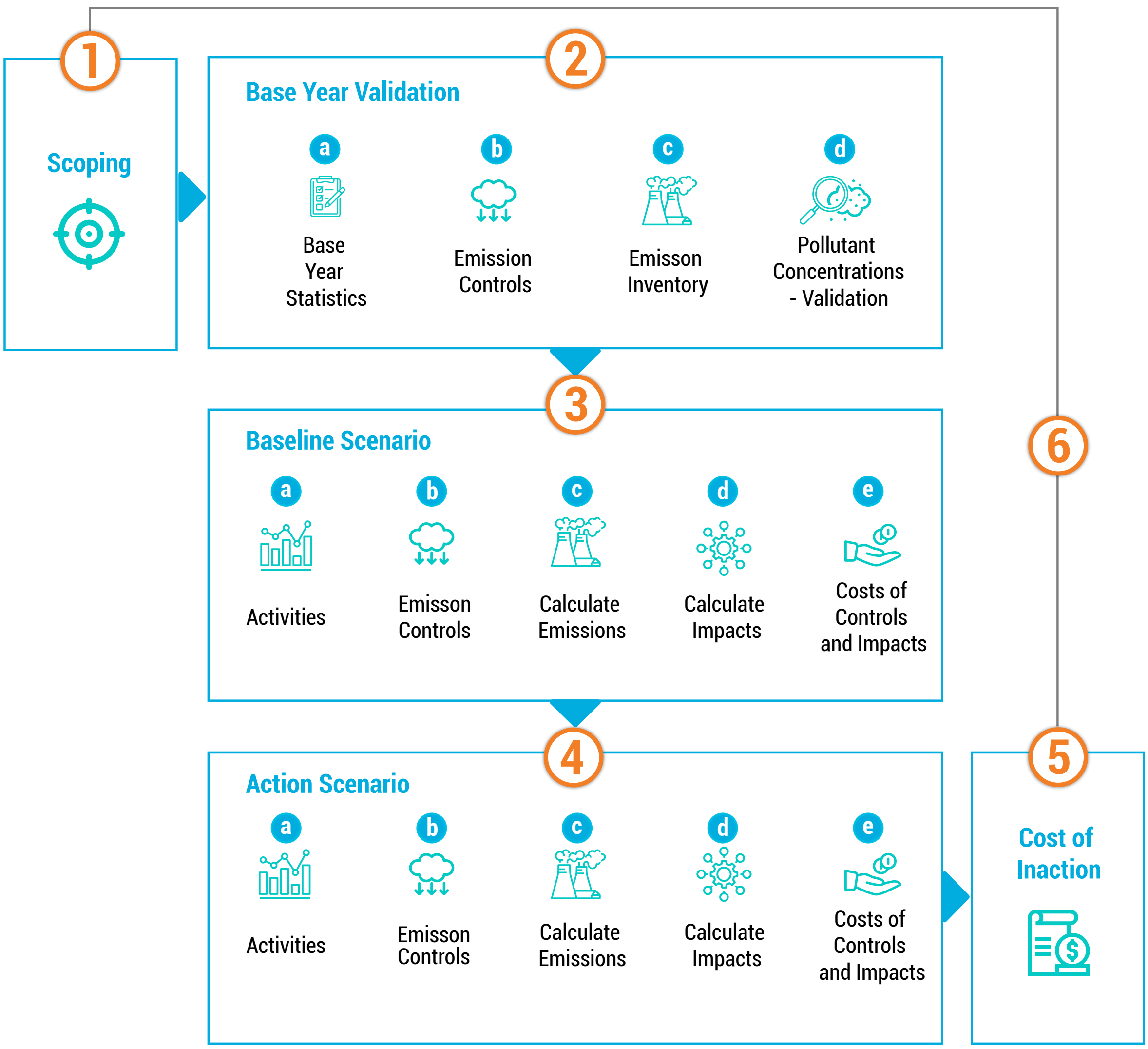


Fig. 3.1 *The six phases of the assessment*

3.1.1. Phase 1: Determine the scope of the analysis

Within the first or 'scoping' phase of the assessment there are multiple key aspects and questions to be quantified before the assessment begins. In this phase, the assessment team needs to develop a joint understanding with relevant stakeholders and technical experts of what will be included in the assessment. In phase 1, the assessment team should plan what kind of assessment might be useful to look at, identify which impacts will be considered, which methods will be used to monetise these impacts and what policy actions will be addressed within the assessment. While they should also identify practical aspects of the assessment including the capacity of the team, the end-users of the assessment, identifying relevant stakeholders, identify available tools (cf Box 7) and develop a strategy, ensuring that they follow good practices (cf Section 2.2.3). The broader the scope of the assessment, i.e. the more impacts quantified, the more complete the cost of inaction assessment and the higher the estimated cost of inaction. However, the broader the scope, the higher are also the demands on data and on the capacity and expertise of the assessment team. Thus, typically a compromise needs to be struck. Fig. 3.2 shows some questions which should be considered by the assessment team within this phase of the assessment.

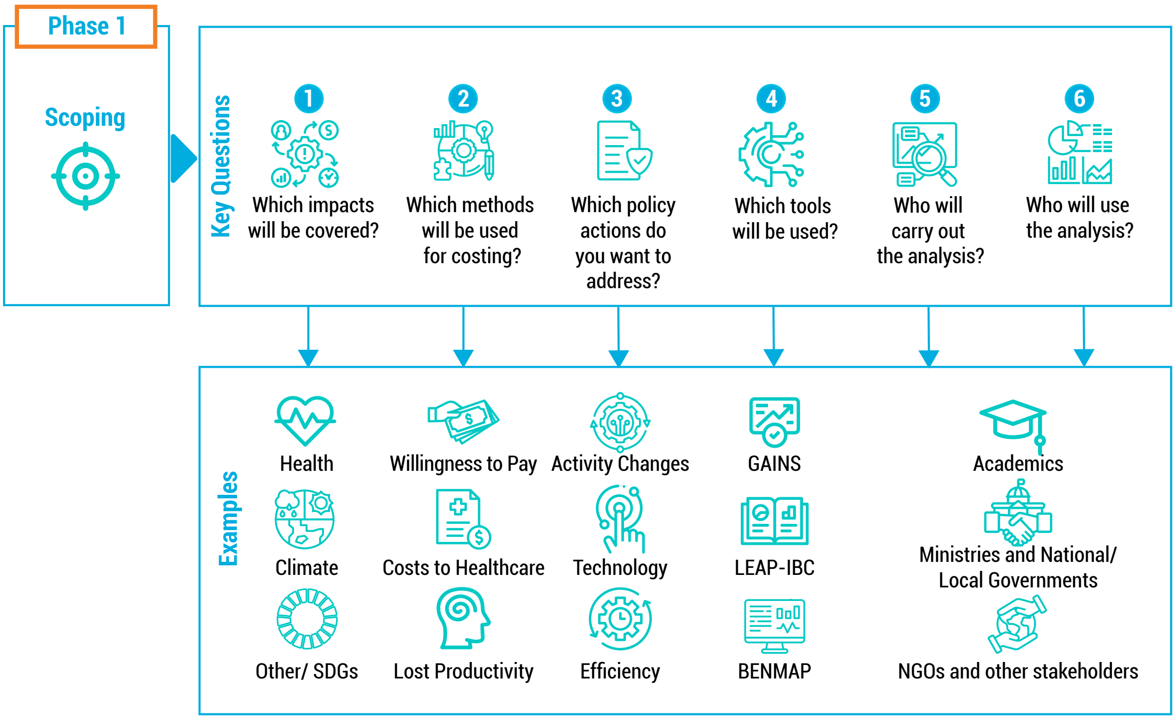


Fig. 3.2 *Key questions that should be considered in the scoping phase (1) of the analysis and some examples of things which could be considered in addressing some of these questions*

A more detailed description of the six key questions and the considerations that should be taken during each of these sub-steps are detailed below:

1. Which impacts will be covered in the analysis?

These could include both mortality and morbidity impacts for health outcomes, climate impacts and other quantifiable or non-quantifiable impacts which might relate to some of the SDGs. To identify which impacts should be the focus of the assessment, the team should consider:

a. Which are likely the most significant impacts and what are the relevant pollutants that will be quantified?

Health impacts (both direct and indirect) of air pollution exposure are likely to be the first focus of a cost of inaction assessment, due to the high proportion of costs that exist in this area. Of all air pollutants, exposure to **$PM_{2.5}$** has the largest associated known health impacts and quantitative methods exist linking exposure to increased risks of developing **COPD, stroke, ischemic heart disease, ALRIs, lung cancer, diabetes, and low birth weight. Mortality impacts from** $PM_{2.5}$, when monetized are often considered more substantial than **morbidity impacts**, though the relative importance depends on the exact circumstances and quantifying both as well as other impacts related to the SDGs. The impacts which will be included in the assessment will depend on the available data and capacity of the assessment team but also on the end-user of the assessment, e.g. the Ministry of Transport may be interested in impacts related to reduced congestion or road traffic fatalities, while the Ministry of Finance may be interested in lost productivity. Considering the end-users of the assessment is therefore important to consider throughout.

b. Which pollutants will be included and how will the emissions of the relevant pollutants be modelled?

In considering which pollutants to model, exposure to **$PM_{2.5}$** has the highest health burden and is therefore often the focus for policy. However, exposure to **O_3** and other pollutants (**NO_x, SO_2** and **CO**) also have health impacts. While some pollutants such as **NO_x, SO_2, NH_3 and VOCs** are precursors for the formation of **$PM_{2.5}$** and so directly quantifying emissions of these precursors will be important in quantifying concentrations of $PM_{2.5}$ and the health impacts associated with exposure. Furthermore, some pollutants such as **BC, CH_4** and Hydrofluorocarbons (**HFCs**) are **SLCPs**, and directly contribute to both air pollution and climate change. There will also likely be some **climatic impacts** in terms of GHG emission reductions from implementing policies related to air pollution mitigation. Quantifying emissions of all air pollutants and GHGs, if possible, may therefore be beneficial as it will allow the assessment team to be able to later quantify the multiple impacts from such emission reductions.

Generally, emissions are modelled by **multiplying activity data** with **corresponding emission factors for relevant source categories**. For the base year, these input data are taken from statistical data (cf below) and studies on the measurement and values of emission factors or, alternatively, international databases. Several modelling frameworks exists that can calculate emissions in this way for a base year. The Intergovernmental Panel on Climate Change (**IPCC**) and European Monitoring and Evaluation Programme/European Environment Agency (**EMEP/EEA**) provide guidelines on how to quantify emissions of GHGs and air pollutants respectively, and often have different methodological approaches available depending on the amount of data which is available for each sector and the relative importance of that sector in terms of overall emissions or policy actions. These differing methods are known as tiers. Higher tier methods require more data, and the choice of method needs to be balanced against the data that is available in each country. What is needed, however, is a framework that can also produce emission scenarios for future years. Multiple tools exist for quantifying these emissions both historically and for future scenarios, all of which will have their advantages and disadvantages. Some examples of these are shown in Box 7: Available tools. Thus, the assessment team needs to decide which of the existing emission modelling frameworks suits their purpose (are relevant pollutants included? does it work with available data?) and how much additional data and sectoral scenarios will need to be collected from other modelling teams or published sources to quantify emissions with the different complexities?

Box 7: Available tools

LEAP

LEAP, the Low Emissions Analysis Platform, is a widely-used software tool for energy policy analysis and climate change mitigation assessment developed at the Stockholm Environment Institute. LEAP is an integrated, scenario-based modelling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy. It can be used to account for both energy sector and non-energy sector GHG emission sources and sinks. In addition to tracking GHGs, LEAP can also be used to analyse emissions of local and regional air pollutants, and SLCPs. The Integrated Benefits Calculator (IBC) that is included in LEAP provides impacts of different mitigation scenarios, through quantifying changes in population weighted $PM_{2.5}$ concentrations for every country in the world based on changes in emissions and this is used to provide the estimates for premature mortality in a country. More information on the LEAP tool can be found at: *https://leap.sei.org/default.asp?action=home*

BenMAP COMMUNITY EDITION

Environmental Benefits Mapping and Analysis Program - Community Edition (BenMAP-CE) is an open-source computer program developed by the United States Environmental Protection Agency that calculates the number and economic value of air pollution-related deaths and illnesses. The software incorporates a database that includes many of the concentration-response relationships, population files, and health and economic data needed to quantify these impacts. This tool can be used to calculate impacts from emissions, and thus in many ways complements the use of tools like LEAP. More details can be found at: *https://www.epa.gov/benmap*

GAINS Online

Greenhouse Gas - Air Pollution Interactions and Synergies

Synergies (GAINS) model explores cost-effective emission control strategies that simultaneously tackle local air quality and GHGs so as to maximize benefits at all scales. GAINS estimates historic emissions of 10 air pollutants and 6 GHGs for each country based on data from international energy and industrial statistics, emission inventories and on data supplied by countries themselves. It assesses emissions on a medium-term time horizon, with projections being specified in five-year intervals through the year 2050. GAINS estimates for each country/region the potential emission reductions that are offered by about 2000 specific emission control measures and their costs. For user-specified packages of measures, GAINS calculates resulting effects on ambient air quality (fine particles, ground-level ozone, deposition of sulphur and nitrogen), and the subsequent impacts on human health and ecosystems. The GAINS model thus covers much of the functionality of LEAP and BenMAP, though while activity scenario data can be stored and used in the analysis, the scenario data themselves need to be developed using a separate energy systems model. More details found at: https://gains.iiasa.ac.at/models/

c. Which statistical data is available to calibrate the calculated emission?

Typically, a **national emission inventory** of some kind may already exist and can be utilized to calibrate or validate the calculated base year emissions. The Electronic Data Gathering, Analysis, and Retrieval (EDGAR) emissions database quantifies sector specific emissions of all air pollutants for most countries, while most countries also have now developed GHG emission inventories as part of the reporting process for the UNFCCC. At the national level **consistency** between the modelled emissions and the inventory needs to be established. As a rule of thumb, depending on the pollutant, a difference up to between 5% and 15% of inventory and model are considered acceptable. At the sectoral level there can be larger discrepancies between the inventory and the modelled data, some of which can be traced to differences in sectoral definitions or accounting schemes. Such differences should be minimized, or at least be noted in the assessment. In general, the higher the sectoral resolution, the higher the uncertainty and potential discrepancy; the more aggregate the comparison, the better the match.

d. How will the impacts be modelled, and which type of model will be used?

To translate emissions into impacts related to ambient air pollution typically a **chemical transport model (CTM)** is used, though in most cases a **reduced form model (RFM)** can be used as well. Ideally a RFM uses national emissions as inputs and performs a **gridding** (i.e. spatial distribution calculation) of emissions only internally. Outputs of CTM/RFM are typically **concentration fields/maps** (e.g. $PM_{2.5}$ or ozone). These concentration maps are then translated into exposure maps by overlaying a corresponding population map to calculate the average population weighted exposure in a specific location. Modellers need to ensure that the concentration fields and the population maps can be made commensurable and can be overlaid, so that a consistent exposure map can be generated. The health impacts due to indoor air pollution may also be included in the analysis. In order to quantify this impact, the fraction of the population cooking with solid fuels, combined with the average exposure (taken from literature) is used to estimate the exposure. Once the exposure has been calculated, health impacts can be quantified following the GBD methodology (IHME, 2020).

e. Which monitoring data are available to validate the concentration calculations?

Base year concentration calculations need to be validated by **comparing them to actual measurements.** One of the challenges is that, while modelled concentrations are typically calculated at the grid cell level and represent the average value for that grid cell, measurement data are available at a particular location or locations at high temporal resolution. Thus, the measured concentration needs to be averaged over time, and then may or may not be representative for the concentration of the whole grid cell. Thus, the assessment team needs to **identify sources of measurement data** and devise and/or apply a **methodology for comparing concentration levels at the appropriate level of representativeness**.

f. Will transboundary impacts (i.e. impacts in neighbouring countries) be included in the assessment?

Depending on the size of the country and the prevalent meteorological conditions these transboundary impacts can be significant. At first sight, since they affect another country, there may be little incentive to reduce them. However, reduced transboundary impacts can be seen as an **asset** in the context of regional cooperation and friendly relations with neighbouring countries.

2. Which impacts will be covered in the analysis?

Some of the most decisive parameters in the cost of inaction calculation are the monetization parameters of the various impacts. However, these cannot be determined exactly and **often involve value judgements**, either in relation to the values themselves or as a choice of system boundaries that are used to estimate their value. For example, making a choice on the monetary VSL or life year involves a value judgement. The cost to society of a sick person can either include only the direct health care costs (which could be estimated from typical costs for doctor visits, drugs consumed, hospitalization, etc.), or also indirect losses related to productivity losses and all associated feedback mechanisms at the macroeconomic level, or even losses as a result of the psychological losses of well-being or quality-adjusted life year (QALY). Whichever approach is taken, it is important that the **monetization procedure of the assessment is transparent** and well documented so that, for example, sensitivities of results to changes in the underlying assumptions and parameter values can easily be estimated and traced. In the context of health impacts, a monetization of the following may be included:

a. Mortality:

Here, often willingness-to-pay (WTP) studies are used to determine the value of statistical life or statistical life year. Since WTP depends on a broader economic context, such as income and wealth of a society and its members, WTP is highly dependent on the state of the national economy and thus international values/values observed in other economies may be of limited validity. Thus, the assessment team needs to identify appropriate sources of information: are WTP studies for your country available? What are ranges of the values? What are international values and how do they compare?

b. Morbidity:

As indicated above, while morbidity impacts have often been treated as secondary, recent scientific work indicates that morbidity impacts can be substantial. The assessment team needs to decide which morbidity indicators to include in the assessment, including **which diseases** and which metrics for measuring them. As also indicated, there is a range of approaches where to **draw the system boundary** for determining the morbidity costs to society, ranging from the **direct costs to the health care system** (e.g. provision of services in hospitals or by doctors to address health impacts related to air pollution, including the costs of medication) to the **indirect effects to the public and private sectors and the whole economy**. Such indirect effects could include, for example reduced labour or overall productivity. A full macroeconomic analysis would typically require the use of computable general equilibrium (CGE) model or similar framework. The assessment team needs to decide, on the basis of available data and tools, as well as on the basis of the preferred accounting framework, which system boundaries and method of monetization will be used.

At this stage you can already classify the impacts to be included as either i) can and will be monetized, and costs are readily included; ii) can be quantified, but not monetized; iii) cannot be quantified, but can become part of a narrative, e.g. impacts on differential or gender equity, etc. Therefore, several impacts that could also be included in a cost of inaction assessment, these include but are not limited to:

c. Other impacts of air pollutants:

Notably, crop damages from ozone can be substantial, and so can be other impacts, such as damages to materials and cultural heritage, though an exact quantification may be difficult. Also, whether such damages can be consistently be estimated will depend on the tools available, as discussed in 2b above.

d. SLCPs:

The quantified emissions of climate-related substances may first be translated into CO_2-equivalent emissions and then monetized by multiplying with the social cost of carbon (SCC), which has been estimated in the literature, though estimates of the appropriate value vary. There are also studies that attach a social cost to different pollutants (such as CH_4) to reflect different potencies over different time scales (Shindell et al., 2017).

e. Road traffic injury:

It is possible to calculate the incidence rate of deaths due to road traffic accidents that can be calculated from data on current accidents by impacting mode and number of km taken by various vehicle modes in a historic year.

f. Non-monetized benefits:

In addition to the economic assessment, a broader interpretation of the 'cost of inaction' could include non-quantified non-valued benefits of action. These cannot be aggregated and would need to be reported separately. They can offer powerful additional qualitative narratives of the costs of inaction.

3. Which alternative (policy) actions will be covered?

To fully utilize the cost of inaction concept, a comparison between (at least) two alternative future scenarios, which differ by the extent to which additional policy action is taken (business as usual versus an 'action' scenario) is necessary. The cost of inaction will depend on what exactly the action consists of and to what extent this action is implemented. For example, the action may consist of expanding the use of a particular technology (say, wind energy with a capacity target), but it may also consist in a whole package of measures that either achieve an overall impact-related goal (e.g. a set of measures that reduces air pollution to a particular WHO target level), or other policy goal (e.g. achieve a say 25% share of renewables in the power fix while improving the economic energy efficiency by say 40%). Actions (related to air pollution management) may be classified as either (i) targeting emission controls ('**end-of-pipe measures**'), (ii) **changes to the supply system** without changing the demand of services (e.g. fuel substitutions in the energy system), or (iii) **changes to the demand system** (that will also result in changes to the supply system). In the context of the cost of inaction, the following considerations will need to be addressed by the assessment team:

i. Are there measures that are already part of the **current national public discourse** and that would be useful to include in the assessment, independently of their actual (expected) effectiveness and costs?

ii. Are there measures that are part of the i**nternational public discourse** that would be useful to assess, e.g. in the context of the SDG, the Paris Agreement, or other international processes?

iii. Which measures likely lead to a **substantial reduction in impacts** (and associated societal costs) in our national circumstances? The assessment team may have already identified such measures prior to the cost of inaction assessment.

iv. And are there actions that can improve **multiple different societal goals** – e.g. mobility, health, air pollution, GHG emissions?

While it may also be useful for the assessment team to consider whether they are interested in also trying to quantify the costs of action and therefore be able to define the 'net costs of inaction'. If this is the case, then the assessment team should also consider:

v. Can the costs of the relevant alternative actions be quantified? Here the general considerations in Box 8 are relevant, as well as the guidance in Step 5 c) below.

Box 8: Quantifying the costs of mitigation action

For some measures, specifically those that involve the use of a technology, costs of mitigation can typically be quantified relatively accurately. Care must be taken **not to underestimate the costs** by considering too narrow systems boundaries. For example, the costs estimate of expanding the use of renewable energy sources is often only including the costs for the solar panels or wind mills, but ignoring the costs for adjusting the infrastructure, i.e. the power grid, back-up capacity and potentially storage. On the other hand, drawing the systems boundaries too wide might result in an overestimate of costs. For example, while a modern and efficient waste management system will result in improved air quality, accounting the full cost of such a system as an air pollution control measure is not appropriate, as such a system will deliver other societal benefits that are beyond the current assessment, having to do with resource and economic efficiency, etc. Thus, the assessment team needs to decide **where to draw the system boundaries** for the cost accounting of taking action. These boundaries are ideally **consistent with the boundaries of the assessment of monetized benefits.**

4. Which tools will be used for the assessment?

Considering the variety of individual steps of the **assessment** to be undertaken and some of the main questions raised above, in the scoping phase the stakeholders need to decide on the **appropriate tools and data sources**. No single framework will be able to address all questions of the assessment, though there exist frameworks (e.g. the GAINS or LEAP-IBC models c.f Box 7: Available Tools) that can cover many aspects and offer an interactive infrastructure and thus can provide a methodological backbone to the analysis. In either case it will be necessary to combine different data sources, and it is useful to **conceptualize the data flow** between the relevant components of the overall assessment framework and the **data management and versioning** in this scoping phase, considering that multiple scenarios will be analysed. It is recommended to do this in the form of a **narrative** (e.g. for what aspect are national data available and can be used, and where can international data help?), **but also at the technical level** (how will the data be transferred and combined, e.g. between different tools? Can tools only use default data, or can own/national data be used, e.g. for vulnerability parameters?). Some relevant available tools are described in Box 7.

5. Who will carry out the analysis?

Experience shows that such an analysis is best carried out by a transdisciplinary consortium whose members are willing to work as a team, can communicate effectively, and are able to work under time pressure. Specifically, during the scoping phase it will be useful to assess:

a. Does the team as a whole cover all of the **required expertise?**

b. Does the team have the **capacity to operate the required tools?** Thus, are they proficient enough with the tools, or do they need training? Are resources allocated to run a CTM, if needed? Does the team have the required time allocated to their regular work plan?

c. **The timing of the assessment.** On the one hand, the planning of the assessment reflects the time needed to carry out each phase of the assessment (internal timing). On the other hand, it is useful to identify opportunities and needs for using the results of the assessment in a timely manner in the context of national or **international policy processes (external timing). Internal timelines and external ones need to be matched** to make the assessment results effective.

6. Who will likely use the analysis?

An assessment of the **uses and users** of the cost of inaction assessment results will help to better understand the needs and the appropriate scope of the assessment. Some of these are also highlighted in the previous Section 2.2.3: Good Practices. For example, it is good practice to engage with stakeholders in the analysis early on in the process and to **co-design the assessment**. This ensures that awareness is raised in the respective stakeholder communities and that the assessment indeed addresses the information needs. It will also be useful at this stage to consider the **communication strategy of the anticipated results**, including the following:

a. The results of the assessment will be subject to **uncertainty**. This could be expressed in the form of ranges of values, or in the form of **sensitivity analysis**. In addition, a resulting strategy could be to use expert judgement, whenever need for it arises, that can be considered **conservative**. Communicated in this way the overall assessment results might be more convincing.

b. The assessment will inevitably involve alternative future scenarios representing alternative policy choices. These futures are generated by models. As such **none of these scenarios is a prediction**, but rather represents an idealised future outcome that is consistent with certain assumptions. The assessment team should be able to clearly communicate that while models have their shortcomings, they are useful for the analysis. The team should also be able to clarify **the notion and value of alternative scenarios**.

c. The assessment depends on a large number of parameters that individually do not affect the overall result much (such as individual emission factors), and also on a small number of parameters that can affect the overall outcome a lot (such as the WTP values, the discount rate, etc.). The assessment team should ensure that they are prepared, by the time of the presentation of the results, to answer questions about certain **methodological choices** and the **relative importance of certain parameter values**.

3.1.2. Phase 2: Quantify and validate emissions in the base year

The objective of Phase 2 of the assessment is to build confidence into the modelling approach taken in the assessment. Since the modelling extends into the future, it is important to first have confidence in the data and methodology used for the historic period before bringing in additional uncertainties into the future scenarios. Hence, in this phase, emissions and concentrations are first quantified for a recent historic or 'base year'. This will be the starting point for the future analysis but can also be used to validate the data and the overall modelling approach, through comparisons with other studies and with historic or recent observational data. This phase can be undertaken in four key steps outlined below and shown in Fig. 3.3.

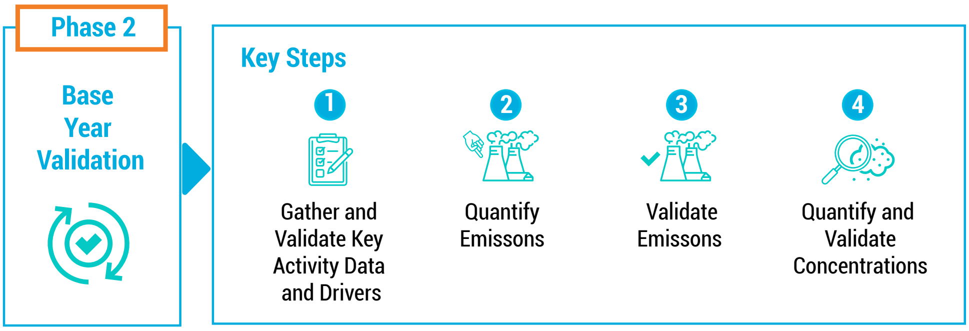


Fig. 3.3 *Key steps involved in phase 2 of a cost of inaction assessment relating to the calculation and validation of emissions and concentrations in the base year*

Step 1: Gather and Validate Key Activity Data and Drivers

Emissions and pollution are driven by socioeconomic activities, such as population and economic growth which impacts energy demand, industrial production, transportation, etc. In this step, the assessment team needs to ensure that the socioeconomic activities and drivers used in the assessment framework agree with statistical data for the base year. Examples of activity data which is needed to estimate emissions from all sectors can be found in the IPCC 2006 and EMEP/EEA 2019 guidelines.

Note: The base year data may be uncharacteristic compared to other recent years (e.g. a COVID year), and may not represent a good starting point for an extrapolation in the form of a scenario. The assessment team should discuss the pros and cons of selecting a particular year for validation purposes.

Step 2: Quantify emissions in the base year

To quantify emissions in the base year, the validated activity data are then multiplied with the appropriate base year emission factors to calculate the base year emissions for each source sector.

Note:

- The main guide that is used internationally for methods and default emission factors is the **EMEP/EEA guide** (European Environment Agency [EEA], 2019). There are different Tiers of methods to estimate air pollution emissions, with Tier 1 methods being the simplest. Tier 2 and Tier 3 methods aim to create more accurate emission estimates and are particularly important for estimating certain emissions from certain sources (EEA, 2019).
- Emission factors of individual sources may change over time, e.g. as a result of deteriorating or failing technologies. Hence, it is to be expected that **current emission factors may differ from past emission factors** in the base year.
- It is important that **local knowledge** about the characteristics of specific sources is reflected in the base year emission calculation. This could be, but is not restricted to: knowledge about specific local practices that affect emissions, knowledge about specific accounting frameworks used, knowledge of relevant publications or databases of emission factors not published in English or which are only accessible to local experts, etc.

From experience of working in Thailand, Cambodia and Laos, there is a lot of national data which can provide detail about national situations, but often in ASEAN, some data needs to be derived from international datasets. National data will tend to be collected in different ways and so the development of emission inventories may not be the same in each country. If comparable data want to be used in regional assessments, then it may not be appropriate to use national datasets. Emission factors appropriate for ASEAN are available from various international sources but there are also national sources of data that are developed from studies in ASEAN countries.

Step 3: Validate emissions for the base year

Once calculated, estimated emissions can be compared to official emission inventories. Good agreement between modelled emissions and official inventories gives decision makers confidence that the emissions modelling framework is trustworthy.

Note:

a. Any difference between base year modelled emissions and inventory needs to be explained and ideally be documented, possibly with the aid of emission inventory experts. If there are discrepancies between modelled emissions and inventory data it needs to be checked whether this can be traced back to a difference in activity data or a difference in emission factors.

b. Statistics and inventory data have typically already been scrutinized and were subject to quality control. However, inventories may contain errors as well.

Step 4: Quantify and Validate Concentrations for the base year

Modelled base year emissions are next used to calculate base year concentration levels. Once emitted, pollutants undergo physical transport by wind, and are deposited or washed out by rainfall. They also undergo chemical transformation in the atmosphere, such as the formation of sulphate from SO_2, nitrate from NO_x, and ammonium from NH_3. These are all then secondary inorganic components of $PM_{2.5}$ and consequently contribute to $PM_{2.5}$ concentrations. Ozone is formed from the precursors NO_x, non-methane VOCs, CH_4 and carbon monoxide (CO) under the action of sunlight. These complex transformations and transport in the atmosphere are modelled in different atmospheric chemistry models (or CTMs) such as the EMEP model, Goddard Earth Observing System (GEOS)-Chem and the Goddard Institute for Space Studies (GISS) models. The results of such model runs are checked against ambient air quality monitoring data.

Note:

a. As described above, the modelled and the monitored concentrations are given at **different spatial scales** (grid cell versus actual monitoring location) and thus cannot necessarily be compared directly. Different modelling frameworks use different techniques to render them comparable. For example, when working with the GAINS model additional analysis of the patterns of settlement and transport structures is used to estimate an urban background effect in the concentration of $PM_{2.5}$ (Kiesewetter et al., 2015), and additional source apportionment and calibration studies can help to identify the contribution of very localized ('street canyon') sources that explain the observed data fully.

b. While monitoring data as well as CTM modelling results are typically available as hourly time series, in the context of cost of inaction **annual averages of concentrations** are useful to work with. These cover the occurrence and effects of episodes only implicitly.

c. Care needs to be taken that the **measurement results are indeed continuously valid**, i.e. that there are neither gaps in the annual cycle of measurements, nor periods in which the measuring instruments were out of calibration.

d. A comparison of annual average values with observations may reveal **possible biases** in the CTM. Some of such biases are already known by the developers and/or the user community of these models. They restrict but do not preclude the validity of the respective model. It is important to document such observed biases and take them into account in the assessment.

3.1.3. Phase 3: Development of a Baseline scenario

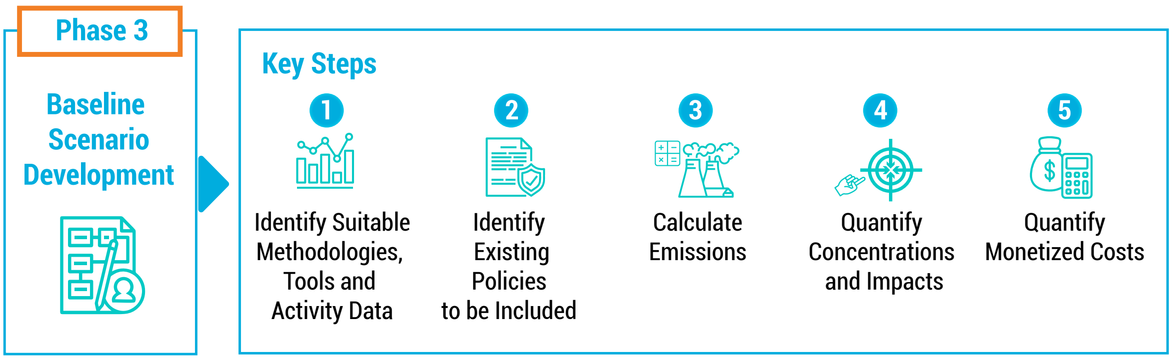


Fig. 3.4 *Key steps involved in phase 3 of a cost of inaction assessment relating to the calculation of emissions, concentrations, impacts and costs for a baseline scenario*

The third phase likely covers the most labour-intensive and time-consuming tasks (Fig 3.4). In particular, preparing and operating a framework that can be used to develop alternative scenarios for drivers and activity data, as well as for translating alternative policy narratives into actual future control scenarios including impacts involves **substantial upfront investment of expertise, data and time**. However, once such as framework is set up properly it can be used to explore a variety of alternative future scenarios that can be assessed (cf Phase 4 below). Generally, a Baseline scenario and its relevant indicators is generated by taking the following steps:

Step 1: Identifying suitable methodologies, tools and available activity data

This step could include identifying what tools are available and how they can be used to complement the chosen tool used in the assessment. For example, energy system models such as LEAP can directly estimate the changes in energy demand for a given scenario and will directly calculate how this energy demand will be met (e.g. through increasing the generation of electricity required). This will generate a baseline energy use scenario. These models can be used both independently to quantify emissions (in the case of LEAP) or can be used as inputs to other models. Similar, agriculture system models can project the production of agricultural commodities and their production systems based on a demand, which in turn may be driven by local demand or a combination of local demand and the net difference between import and export. Ideally a coherent set of assumptions is used across such models to generate consistent future activity data.

If such sectoral models (energy, industry, agriculture, transportation, etc.) are not available, very simplistic future scenarios of activity data can be generated by using future pathways of socioeconomic drivers and parameters, such as population or GDP, to scale future activity data. In the absence of dedicated tools, this could be done in a spreadsheet tool. There are multiple international default population projections including the World Bank and UN Population Projections. There are standard simplified methodologies for how you might project baseline activity, including elasticities between GDP per capita and transport demand, waste, diet, energy consumption per capita, etc.

Ideally, a Baseline activity scenario that is used for the assessment of the cost of inaction is a scenario that is broadly or even very specifically consistent with the Baseline scenario used for other policy purposes. For example, the assessment team may use a scenario that has been developed for the Ministry of Energy for future energy planning purposes. The assessment team should get an overview of where scenarios are already being used and in which way, and which national modelers are involved in such processes. In this way the cost of inaction assessment acquires relevance and pertinence for national decision-making processes.

Step 2: Identify existing policies which exist to develop a Baseline Emission control scenario

In this step it is important for the assessment team to identify what existing policies have already been implemented which will likely have an impact on future emissions. Therefore, the assessment team should:

a. Review all relevant policies that are to be considered part of the Baseline scenario. Policies that are only currently being discussed but are not part of legislation should not be included. Policies that affect the activity data should already be reflected in the activity data scenario (cf. Step 1 in above Section 3.1.3), so here the focus is mostly on policies that regulate the use of emission control technologies and standards.

b. Translate the baseline policies over time into relevant emission factors that represent these policies. For example, in sophisticated assessment tools like the GAINS model policies are translated into shares of representative technologies, and these shares can change over time. For example, the relative share of vehicles subject to different Euro standards changes over time, as new standards are introduced and older standards are phased out.

Step 3: Calculate emissions for the baseline scenario

Using the projected activity data and emission factors in the previous two steps, the assessment team should now be able to quantify the emissions of all relevant pollutants and GHGs. The methodology used in this step should follow that identified in Phase 2 and should follow the IPCC and EMEP/EEA guidelines.

Step 4: Quantify concentrations and impacts for the baseline scenario

Using the baseline emissions and the impacts framework identified during the scoping phase, in this step the baseline impacts are calculated. For calculating concentrations and health impacts, this may require exporting the results from an emission calculation framework and importing it into a framework that calculates concentrations from given emissions. In an integrated framework like GAINS or LEAP-IBC, the concentrations and impacts can be calculated in a single step without the need of transferring data.

a. Calculate the relevant concentrations, using the same impacts framework as in the validation of modelled observed concentrations (cf Section 3.1.2 item 3)

This will typically include the concentration of $PM_{2.5}$ at the grid cell scale. This concentration map needs to be overlaid with a population density map to calculate exposure. High-resolution population data is typically available at the level of administrative units, such as counties, etc. These then need to be mapped to the grid on which concentrations are calculated. Such a mapping between administrative units and grid cells is done by mapping Geographic Information System (GIS) shapefiles to grid cells. Alternatively, the population exposed to a given concentration can be estimated by using data interpolated from monitoring and population density. The latter is only valid if there is a relatively dense network of monitoring stations, which we know are lacking in many ASEAN countries. Often, population density maps are not projected dynamically into the future, i.e. it needs to be assumed that the spatial population distribution does not change over time. Nevertheless, in order to calculate the future baseline impact the future total population needs to be taken into account. It is also important that the population data used for exposure calculations are consistent with the population data used as drivers for socioeconomic activities (see above).

b. Quantify the health impacts based on estimates of air pollution exposure, information on vulnerability (baseline mortality rate) and population demographics

For air pollution, typically concentration-response functions are used and are generally taken from international data. The WHO and others including the Health Effects Institute use different updates of the concentration-response functions (which calculate the impact due to a given concentration), but now these are fairly mature and the difference from using different functions is relatively minor. The research behind these functions are very large studies with tens of thousands of people, and have traditionally been undertaken in North America and Europe. However, there are now studies included from China and other Asian countries and these are consistent with the European and North American results which provide more confidence in the applicability of these methods to various regions. Equivalent concentration response functions also exist with premature mortality in relation to the impact of O_3. While, in addition to the quantification of deaths from exposure to ambient PM, standard methods also exist to quantify the premature mortality related to exposure to indoor air pollution. These typically use expected PM concentrations and exposure due to using different fuels and technology for cooking from literature studies. From these exposure levels, concentration-response functions and health impacts can be calculated following methodology applied by the GBD.

In addition to functions for premature mortality, there are an increasing number of concentration-response functions for other non-fatal health outcomes. This includes the impact of $PM_{2.5}$ and ozone on pre-term births, on low birth weight, on non-fatal strokes and heart attacks, Type 2 diabetes, bronchitis and emergency room visits related to acute asthma attacks. There is also increasing evidence that air pollution has many other effects on health, such as reduced cognitive ability, reproductive health, etc.

Useful data and data sources:

i. **Baseline mortality and morbidity rate** (age and gender disaggregated by specific cause of mortality or disease) are available from the GBD (Murray et al., 2020) which is disaggregated by sex and age and from national statistics. However, national data is not always disaggregated by age and sex, which makes it difficult to apply to get age and health disaggregated health impacts.

ii. **Morbidity data:** In order to estimate the morbidity impacts, data can come from international sources (e.g. GBD) or from national data on hospital visits for a specific reason, number of asthma attacks, incidence of pre-term births, low birth weight, etc.

iii. **The Demographic and Health Survey Programme** (*https://www.dhsprogram.com/*) reports often have information on child and maternal mortality and health issues such as low birth weight, etc. and the incidences of different diseases for under 5 year-olds.

Example Limitations:

- In Thailand, private hospitals do not have the same reporting duties as public hospitals, which may lead to undercounting of admissions for respiratory problems. This may have changed since COVID- 19, but highlights the need for a comprehensive reporting mechanism to understand the full health burden.

c. Quantify other indicators from the Baseline scenario as agreed in the scoping phase

These calculations do not have to follow the same steps as the health-related indicators. There are multiple other associated impacts and costs directly related to air pollution but also other areas which will be impacted by air pollution policies. For example, you may decide to include the social costs of carbon related to GHG emissions, or the impacts from air pollution on crops (see the example below).

In addition to the adverse health impacts associated with air pollution and O_3 pollution can also significantly impact crop and forest yields with implications for global food supplies. This can further impact human health, particularly in regions where malnutrition is high. Between 3% and 16% of the yield of four staple crops are estimated to be lost due to exposure to ozone each year and yield losses locally can be much higher. Estimates of the impact of ozone pollution on crops can utilize concentration-response functions which are available for rice, wheat, soybean and maize and are widely used. There are also associated functions for timber production although this is limited to a small number of tree species. Therefore, whilst it is possible to estimate the impact of air pollution on crops using existing methodologies, the research for several crops and commercially important trees is lacking in many cases. The other issue with estimating ozone impacts on crops is that there is not a linear relationship between emissions of ozone precursors and concentrations of ozone. This means that to understand the impact of different scenarios on ozone concentrations, specific ozone atmospheric models will need to be run and combined with emissions assessments.

Step 5: Quantify monetized costs of the Baseline scenario

This includes all the monetized impacts as agreed in the scoping phase, i.e. potentially the direct and indirect health costs, the valued costs of carbon emissions, and other costs. For a visual explanation and application of these costs for a cost of inaction assessment in Thailand, see Box 10.

a. Direct Costs of Inaction

There are standard methods to estimate direct health costs, such as visits to hospital and staying in hospital, cost of medication, etc. Economists have concluded that the most appropriate method to quantify the direct cost from people dying prematurely due to air pollution exposure is to use the 'willingness-to-pay approach', where people in different countries are asked how much they are prepared to pay to avoid the low risk of dying from air pollution. The results of these surveys are then used to provide a VSL. Multiplying this VSL by the number of people who are estimated to die prematurely due to air pollution exposure gives the total cost from premature mortality in a given country and a certain year due to exposure to air pollution in the baseline scenario. The 'Value of a Life Year' can also be used to quantify the cost of air pollution exposure, while the 'Number of Work Days Lost' and the 'Number of Hospitalizations' are other metrics which can be costed and quantified in order to paint broader picture of the morbidity impacts of air pollution exposure.

b. Indirect Costs of Inaction

The concept of 'indirect costs' relates to the question of whether the cost of air pollution is only related to direct costs or whether the costs are much greater. Quantifying the magnitude of the broader cost to society is difficult, and various methods have been used such as wage differential between risky and non-risky but similar jobs. The economic importance of different impacts other than health have been estimated in different context, usually in Europe and North America. This includes the costs of congestion which tend to be large, and the cost of road traffic injuries, and a quantification of the economic benefits of active transport. Again, quantifying these in the cost of inaction only makes sense if the 'action scenario' is expected to affect these impacts.

c. Costs of Action

As shown in Fig.1.1 of Section 1.1 above, the Baseline scenario cost is used in the cost of inaction calculation. Although the costs of action do not need to be quantified to perform a cost of inaction assessment, it can be useful. The cost of inaction may be complemented with the 'cost of action' to get a balanced account of relative merits of taking action. This 'cost of action' assessment includes calculating the costs for implementing emissions controls in the Baseline and in the Mitigation scenario, respectively. This is sometimes called the cost of mitigation.

There are different costs associated with mitigation of air pollution and it is important to understand which costs are borne by which stakeholders. In air pollution research for policy, the most commonly estimated costs relate to the cost of implementing different measures. These can vary between one off technological or infrastructural costs or prolonged costs which continue through the implementation of the policy. For example, individuals may need to bear the cost of buying new Liquefied Petroleum Gas (LPG) cookstoves to replace traditional wood-fuel stoves, this is a one-off cost, but buying LPG to cook with is an ongoing cost. This ongoing cost may be borne by the individual but could also be subsidised by government. Another example could be increased public transport provisions, again there is an associated one-off cost to governments such as infrastructural costs to develop a mass rapid transit system but there are also costs associated if governments want to incentivise use by keeping prices low. Governments may also need to bear the costs related to mandating emission controls for nationalised industries. The private sector will need to bear the cost of implementing pollution mitigation measures. There are also other costs – such as the costs borne by governments to plan implementation of different measures or the costs of awareness raising campaigns. These costs are less frequently evaluated but are sometimes estimated. Box 9 details how to go about setting up an analysis for quantifying some of the costs of action.

Box 9: Setting up a costing analysis

To set up a costing analysis, it is first necessary to draw a boundary around the system in question and ensure that there is no double counting. For example, if you count the costs of fuels used to generate electricity you should not also count the cost of the electricity in an overall cost-benefit calculation. The following considers the different costs and how they can be estimated.

Technology cost data: For a particular policy where one technology is replaced by another, one can specify the total cost of competing devices used in a reference of policy scenario, or you can enter the incremental cost of the new devices introduced in the policy scenario relative to the costs of devices used in the reference scenario.

Cost of energy saved: Data can also be entered in the form of the cost of energy saved, relative to a reference scenario, for consuming a particular fuel in a particular sector. This can be used when source sectors are not specified in sufficient detail to enter technology specific data.

Transformation costs: Each of the demand side policy options will have impacts on the size and operation of the Transformation sector. To capture costs associated with changes in the transformation sector (e.g. changes in electricity generation), then it is necessary to specify for all the power plants and fuels used (e.g. to generate electricity). Costs can be entered as capital costs ($ per Megawatt production capacity), fixed Operation and Maintenance (O&M) costs ($ per Megawatt production) and variable O&M costs ($ per Megawatt-Hour production). The lifetime of the action/technology in this sector is required to spread out the capital cost across the lifetime of the intervention.

3.1.4. Phase 4: Development of an alternative action scenario

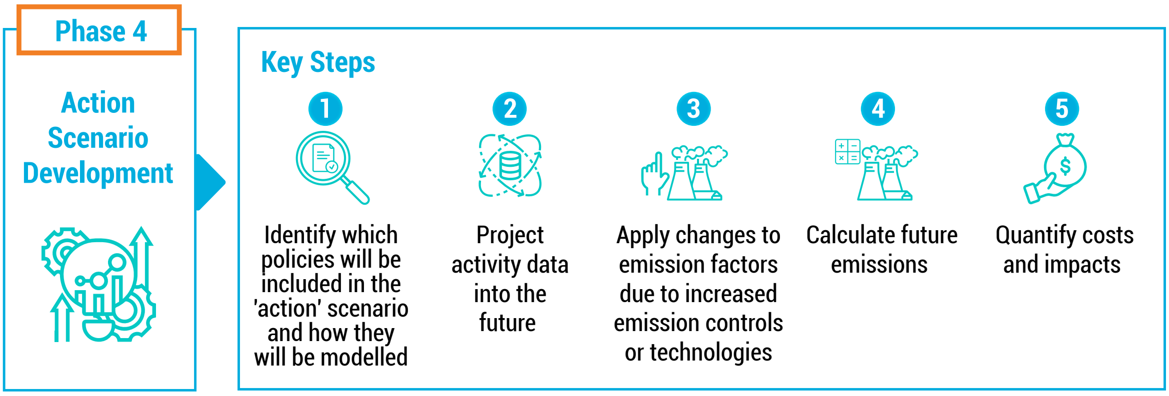


Fig. 3.5 *Key steps involved in phase 4 of a cost of inaction assessment relating to the calculation of emissions, concentrations, impacts and costs for an alternative action scenario*

In this phase, an alternative ('action' or Mitigation) scenario is developed, following essentially the same steps as for the Baseline scenario (Fig 3.5).

Step 1: Identify policy actions to be included in the scenario

First it needs to be determined which alternative actions, policies and measures should be considered as part of the analysis to reduce emissions. Priority measures should be identified, preferably with multi-stakeholder engagement, including the ministries and other stakeholders who would be responsible for the implementation. Each alternative action, policy and measure can be evaluated against their overall potential to implement them.

Note that the assessment of some of the measures requires alternative activity data, while others require alternative projections of future emission factors.

Step 2: Project alternative ('action'/Mitigation) scenario activity data and develop an alternative ('action'/Mitigation) emission control scenario

Depending on the scope of the measures to be analysed, these activity data may be identical to the baseline activity data. For example, if the 'action' includes changes to the energy system or other production systems (e.g. more renewables, more electric vehicles, alternative diet scenarios, etc.), then an alternative set of activity data needs to be developed. In contrast, if the 'action' to be analysed only includes end-of-pipe measures that reduce emissions (e.g. Euro standards, sulphur scrubbers, etc.) but not the underlying activity data, then the same activity projection as in the baseline can be used and there will be a change in the emission factors, consistent with the approach taken in Step 2 in above Section 3.1.3.)

Step 3: Calculate future emissions for the Mitigation scenario

Step 4: Calculate future (reduced) impacts in the alternative Mitigation scenario

Step 5: Calculate the cost of the alternative ('action'/Mitigation) scenario

3.1.5. Phase 5: Cost of Inaction as Difference

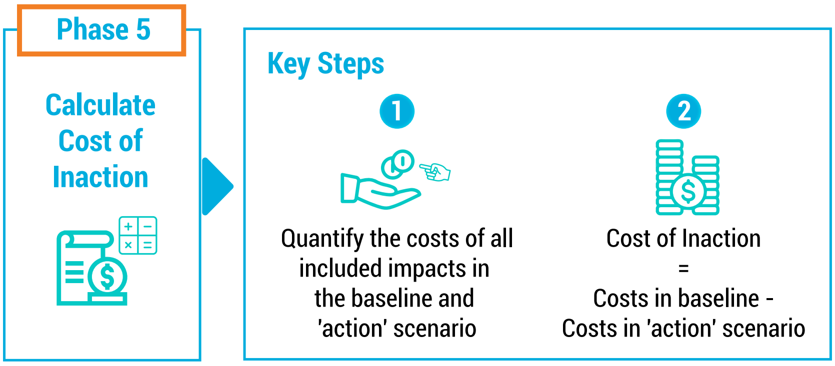


Fig. 3.6 *Key steps involved in phase 5 of a cost of inaction assessment relating to the calculation of the costs of inaction*

Once the costs of the Baseline scenario and of the Mitigation scenario have been established, the **cost of inaction** can be established as the difference between these costs for a given year (Fig. 3.6). By construction, the costs of the two scenarios should be consistent, as the same impacts have been analysed with the same methods.

Note:

- The cost of inaction is typically calculated for a **single future year**. Reporting a trajectory of cost of inaction for several future years is also possible, though typically the focus of the analysis will be on a period over which realistically the policy changes analysed could be implemented
- As noted above the calculated cost of inaction will depend on the exact valuation method for the impacts, including the VSL. Thus, a different choice in the valuation parameter will change the results, typically proportionally. It is useful to document what **plausible ranges of valuation parameters** are and to illustrate what the **corresponding range in calculated cost of inaction** is.
- At this stage of the assessment, it is important to double check that the costs are accounted consistently across different effects.

3.1.6. Phase 6: Iterate and refine

Going through the above 5 phases allows you to calculate the cost of inaction consistent with the scope of the assessment. The assessment so far may also offer new insights into which part of the analysis may benefit from additional scrutiny, an upgrade of methodology or a change in system boundaries. For example, the analysis may reveal that:

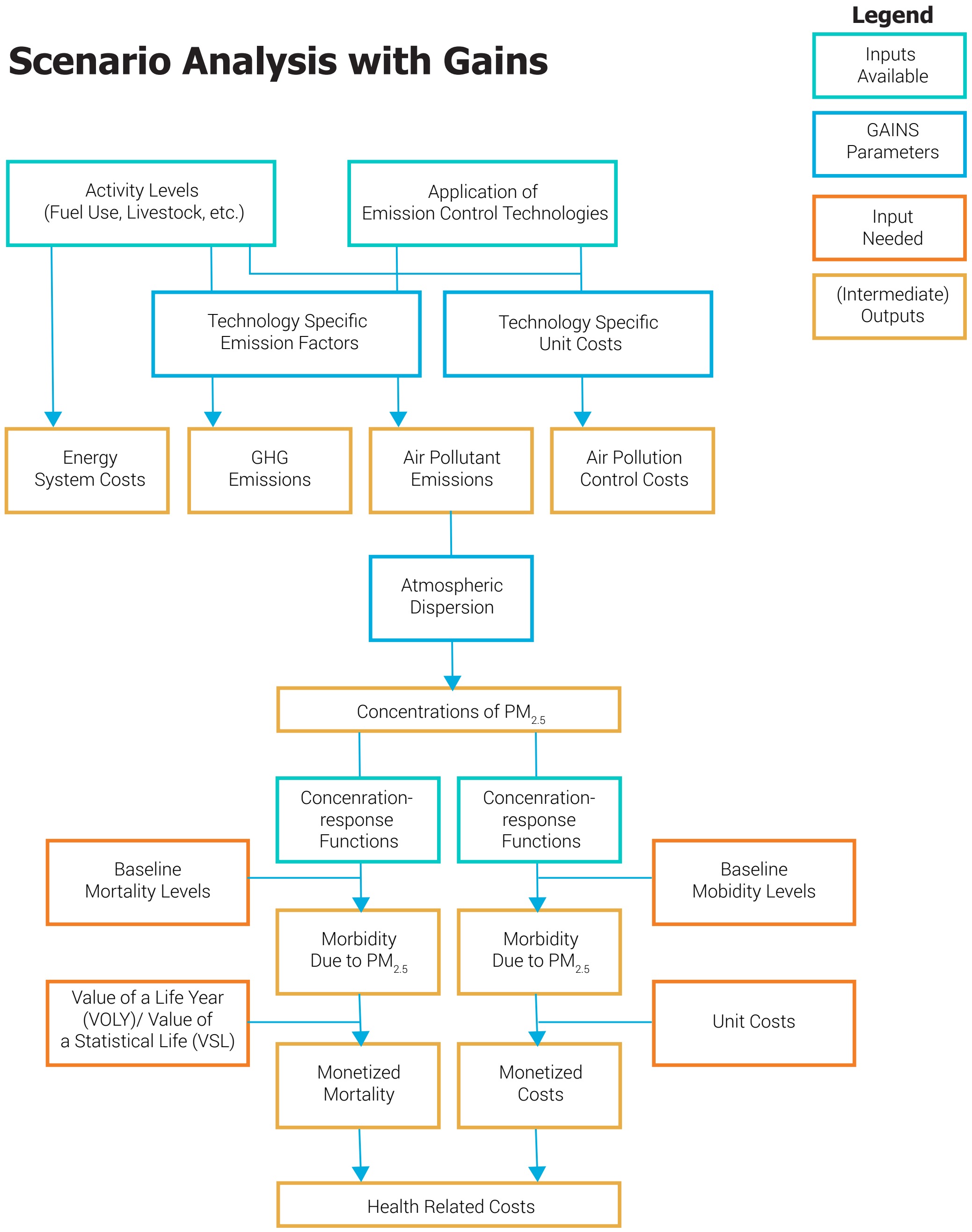
- the emissions from certain source categories are particularly prominent and therefore have a substantial impact on the baseline results. They may also appear to offer large potentials for reductions, and therefore also contribute substantially to the cost of inaction. Therefore, it may be useful to give such "**key categories**" particular attention during a refined analysis to ensure that the implications of an action on such categories are neither over- nor underestimated.
- a "key category" in the emission inventory may stay a key category also in a future scenario, in which case it should receive particular attention (see above). However, the relative prominence of a source category may change over time, and recently small sources may become large in the future. Thus, a key category analysis both in the base year and in a future year of interest may be useful to reflect new insights from **trend analysis**.
- The relative importance of mortality and morbidity costs, as well as other costs may change over time. This may suggest that the analysis of morbidity costs may need to be **refined relative to the original scope of the analysis**.

It is recommended, with the draft results of the cost of inaction analysis at hand, to revisit the choices made in the scoping phase, with respect to systems boundary and tools. Initial results may change the list of priorities for the analysis.

In principle, the cost of inaction analysis can be applied to **individual measures** (e.g. the method can be applied to, say, the question what is the cost of not implementing strict sulphur controls on industrial combustion plants), or to **whole packages** (e.g. a package of measures that would reduce ambient concentrations to a WHO target value). The analysis of packages may reveal further synergies or trade-offs between different measures. It is important **not to double count** the cost of inaction when combining the results from alternative but overlapping measures. For example, either applying best available technologies to coal-fired power plants or replacing them with renewable energies will both reduce emissions and impacts substantially and may lead to similar cost of inactions. Yet, naturally, doing both does not result in a cost of inaction that is twice as high.

Box 10: Case study of a cost of inaction assessment focussing on health impacts from $PM_{2.5}$

The GAINS modelling framework has been specifically applied for cost of inaction assessments in Cambodia, Thailand and Indonesia, focusing only on the costs associated with the health impacts of $PM_{2.5}$. The figure presented here shows practically how a cost of inaction assessment in the GAINS Framework could be performed through directly quantifying the costs of different scenarios (Phase 3 and Phase 4). This gives examples of how a cost of inaction assessment could be performed using the GAINS framework, including what data is already included from international and national level data sources and what specific additional data would be required as an additional input and in the case of this assessment was collected as part of the consultation process.



3.2. Good Practices

The use and uptake of the results of a cost of inaction assessment depend on several factors, some of which are related to the scope and rigor of the assessment, the overall quality of the report and associated products, as well as the communication strategy. There are multiple stages in the development of a cost of inaction assessment (detailed in section 3) and there are different steps that can be taken at each stage to ensure that the cost of inaction assessment will be utilized and effective in its goal. Here we recommend some good practices that should be followed in a cost of inaction assessment to help ensure effectiveness and impact.

1. Communication

Effective communication, throughout the assessment process is essential to ensure buy-in and understanding of key stakeholders and to ensure that everyone involved in the process has full understanding of how the assessment has been undertaken and what the key results are. An effective communication strategy addresses a whole range of questions, including which products will be developed (e.g. a report, a website, a presentation), who is the target audience for each product, and which channels will be used. Some key good practices that should be considered in an effective communication strategy are outlined below:

Good Practice #1: Identify critical points in the timeline of the relevant decision-making process and align the development and release of the assessment with this timeline.

Good Practice #2: Give full public access to methods, tools, data, and results of the assessment using the FAIR data principles to ensure transparency and reproducibility of results.

Good Practice #3: Ensure results are clear and accessible and consider developing infographics that convey key messages in a clear and concise manner.

Good Practice #4: Develop strategies to engage specific communities in the dissemination process and raise public awareness of the assessment. Consider engaging those communities who would most benefit from action (e.g. those who feel the largest impact from inaction).

2. Co-design and consultation

Co-design and consultation increase the relevance and immediacy of the results to stakeholders; they create transparency, which in turn increases trust into and the legitimacy of the assessment; they also create a sense of ownership of the assessment with the stakeholders, which enhances the acceptability of assessment results. The assessment process, when it is co-designed and carried out in close consultation with relevant stakeholders, also offers the basis for developing a joint understanding of the relevant concepts and challenges, and a common language to discuss and address these. As experience from other regions in the world shows, it is difficult to overestimate the benefit of this joint understanding and common language to the national decision-making process on air quality management. More broadly, the cost of inaction assessment process can serve as a role model for further developing and strengthening a political culture that is evidence-based and guided also by scientific insights.

Good Practice #5: Identify the relevant departments, ministries, planning commissions, agencies and associations as stakeholders and involve them in the co-design of the assessment.

3. Institutional Development

Beyond resources in terms of time, expertise, data, tools and finances, the technical assessment of the cost of inaction requires institutional support. Institutions could enhance the success of costs of inaction assessments through promoting settings that are conducive to developing, conducting and using assessments:

Good Practice #6: Enhance cross-government coordination mechanisms that result in harmonized environment and health policymaking. These could include inter-ministerial working groups or task forces that meet regularly, joint agenda-setting and decision-making processes, and a process of developing joint assessments.

4. Capacity Building

To ensure the success of costs of inaction assessments, it is essential that the assessment team have the skills and knowledge to carry out the analysis. Capacity and awareness-raising also needs to be developed with key stakeholders, so they can effectively contribute to the co-creation process and facilitate the flow of information and data across knowledge domains and constituencies.

Good Practice #8: Ensure that the assessment team and key stakeholder have opportunities and time to develop capacity and have access to any resources that may be needed to undertake the assessment.

5. Equity and Inclusivity

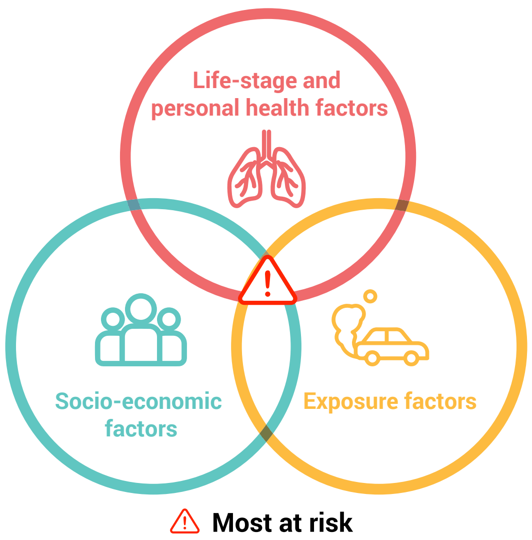
Finally, it is important to consider which groups bear the largest costs from air pollution and how different groups could be impacted by various policies.

Box 11: Understanding the differentiated costs of air pollution

The impacts of air pollution are not felt equally across a population. Some groups are more exposed to air pollution, due to the locations or activities where they spend their time, while some groups are more susceptible to the health impacts of air pollution. Those at highest risk, will therefore be people who experience high levels of exposure and simultaneously are extremely susceptible to the impacts of such exposure. At the same time, mitigation measures will also have different impacts on different groups. Some may perpetuate inequalities, while others may help to reduce inequalities, for example transitioning to modern cooking fuels can have large positive impacts, for all of the society but particularly for women (cf Box 2).

Specifically understanding which groups of society are the most impacted by air pollution and the measures introduced to mitigate it, can provide valuable evidence for the basis of policy development. Air pollution health impact assessments can be used to directly quantify the differences in the health burden associated with air pollution exposure for some of the different subgroups of a population through using age and gender disaggregated baseline mortality rates. A cost of inaction assessment could therefore be used to quantify the costs of not implementing different measures on specific subgroups of society, both in terms of the health impacts of air pollution exposure but also of not realising the multiple co-benefits which could come from implementing such measures.

The most vulnerable groups to air pollution



Life-stage and personal health factors

old age, young age, pregnancy, pre-existing health conditions

Socio-economic factors

poverty, education level, gender, migrant status, ethnic group, access to health care, access to social welfare, working or living in informal sector

Exposure factors

living near polluting industry or agricultural burning; traveling on or working near congested roads; using charcoal, wood or kerosene to cook indoors; working in a polluting industry

Good Practice #9: Mainstream gender throughout the assessment process, including in the co-design and scoping phases outlined in Section 3, and in the analysis and communication of results. The ASEAN gender mainstreaming strategic framework gives examples of how this can be done (Box 6).

Good Practice #10: Where possible use gender-disaggregated data and methodologies in the assessment. Examples could include in health impact assessments or while quantifying the societal costs of different measures.

4. Challenges, Opportunities and Recommendations

This guide has aimed to provide information and evidence on how to perform a cost of inaction assessment and how and why such assessments can be useful. A first national assessment of the cost of inaction likely will not be fully comprehensive. It will, however, also offer opportunities to identify local challenges as well as gaps in data, methods, and capacity. Filling these gaps will not only improve subsequent assessments of the cost of inaction, but more generally will develop national capacity at the science-to-policy interface to carry out assessments more broadly related to air quality management, GHG mitigation, the SDG agenda, and others. In this section, we identify some challenges that the assessment team may face throughout the assessment process as well as the multiple opportunities that can come from performing cost of inaction assessments, as well as potential end uses of such assessments. Finally, we provide a few final recommendations for ASEAN countries to maximise the impact of cost of inaction assessments and utilisation of this guide.

4.1. Challenges and Opportunities

There are several challenges related to a cost of inaction assessment that the assessment team can expect to experience, and which should be considered throughout the assessment. While undertaking a cost of inaction assessment will also provide multiple opportunities for overcoming some of these barriers and challenges. A few of the challenges that the assessment team may face relate to:

- **Applicability of models to all contexts.** Typically, assessment tools can be applied to different contexts and regions of the world. However, they also typically need to be calibrated to the specific local conditions, which requires time, expertise, and local data, not all of which may be readily available.
- **Quality of data/lack of local data.** Poor data quality, if undetected, can lead to unjustified confidence in assessment results with possible loss of trust of stakeholders in the process later when deficiencies are discovered. The lack of local data may affect the confidence that stakeholders have in the results. It is important to be conscious and transparent of data quality. It is good practice to identify steps to improve input data during the assessment and also beyond.
- **Limited disaggregation of data.** For example, energy statistics and models may not offer sufficient disaggregation of data to ensure that the resulting emission inventories are accurate. The absence of, e.g. gender or age information means that differential impacts on women or children cannot captured. Likewise, while the total number of hospitalizations may be available, it may not be possible to identify those that are related to air quality related symptoms. In such cases assumptions need to be made about which values can be considered representative or can be used as averages.
- **Limited coverage of effects.** All the above will result in the need to exclude effects/impacts from the analysis for which either data, tools or expertise are lacking. In practice, this is inevitable even for national systems in advanced economies; a coverage of 'all' costs cannot be expected. Thus, it is important to focus on those effects that have the most significant impact on the cost of inaction, but understand that focussing only on a subset of quantifiable impacts will likely underestimate the calculated costs.
- **Limited assessment capacity.** The assessment team will need to cover or develop expertise in a large variety of disciplines, methods, data and tools. The smaller the team, the less likely that all these are covered initially. It is good practice to reserve time and resources for members of the assessment team to receive training in the relevant methods and tools.
- **Lack of alignment between assessment and national-scale decision making processes.** The challenge goes both ways: on the one hand the assessment process itself needs to be carefully planned so that assessment results are ready to be used when the decision-making process needs them. This means that a clear and realistic timeline needs to be agreed upon by stakeholders and the assessment team. Conversely, for the assessment results to be used effectively, the policy planning and decision-making process needs to be designed to take up and use the cost of inaction assessment results.
- **Lack of incentives for academic researchers to engage in the assessment.** Parts of the assessments would benefit from expertise that is typically found in academia. Recruiting this expertise may be challenging for a number of reasons: lack of funding, perceived lack of academic merit associated with the assessment, unease to work in interdisciplinary teams, etc. It is useful to consider appropriate incentive systems that have currency with academic researcher, including co-authorships, functional titles, research grants, etc.

There are multiple benefits from undertaking costs of inaction assessments and the process of undertaking a cost of inaction assessment will also provide multiple opportunities which could help to address some of the challenges above. These include the opportunity to:

- **Raise awareness of the cross-cutting nature and multiple impacts of air pollution.** Through performing a cost of inaction assessment, the multiple impacts, and costs of inaction of air pollution can be communicated to multiple stakeholders. This can increase awareness and provide evidence for promoting action which in turn may help to promote financing to aid the implementation of such actions.
- **Provide a framework for an integrated and multisectoral approach to air quality management.** Inclusion of stakeholders from multiple sectors and groups throughout the assessment process and clearly communicating the results to everyone involved, could provide an opportunity for developing a framework for a multisectoral approach to air quality management. This in turn may also aid in the development of air pollution policies which can be integrated across different sectoral plans.
- **Enhance capacity of academics, government members, policy makers, NGOs, etc.** Through undertaking a cost of inaction assessment, it is likely that members of the assessment team as well as others may undergo training or enhance their capacity through following detailed guidance as detailed in the document. This will embed capabilities at the national level and will also enhance the capacity of national teams and decision makers to perform and utilize similar assessments in the future.
- **Strengthen the science-policy interface.** The assessment guidelines promote including multiple stakeholders throughout the assessment process and having a clear communication strategy which can be used to highlight key messages to policy makers. Including key stakeholders through the assessment process and having a clear communication strategy could therefore enhance the science-policy interface.
- **Strengthen regional cooperation and share good practices.** The guide presented here details multiple good practices which should aim to be followed when developing a cost of inaction assessment. It is likely that the assessment team, while going through the assessment process will also come up with their own good practices based on their experience. There is therefore an opportunity for ASEAN countries to promote and share their experiences and own good practices, which could strengthen cooperation for performing such assessments in the region. While including the impacts of transboundary air pollution in cost of inaction assessments can also enhance the motivation for implementation or development of policies at the regional scale.

4.2. Recommendations

Overall, it is recommended that the assessment team consider each phase of the assessment process carefully, ensuring that they are aware of the potential limitations and challenges which they may face. This could allow for future improvements in performing cost of inaction assessments and experiences which could be shared across other countries in the ASEAN region. **Overall, it is recommended that ASEAN countries consider:**

- **Establishing dynamic interfaces to national systems, and establishing coherent and updatable databases with national statics, including energy and production statistics,** household survey data, vehicles registrations, imports and exports; health systems data, such as hospitalizations; spatial demographic data; measurement data, etc. Aiming to implement FAIR data principles within the government may improve efficiency in data sharing substantially.
- **Establishing a dedicated national centre of expertise** to allow for a continuous and dedicated engagement of scientific expertise in policy processes. Such a centre could convene experts from different fields of academia and recruit them into the assessment process, thereby potentially offering an effective interface between research and government. The way the EMEP, Centre for Integrated Assessment Modelling (CIAM) works may serve as a template or source of inspiration.
- **Encouraging the attendance of trainings on tools to enhance in-house capacity.** The main tools mentioned in this document (LEAP, BenMAP, GAINS) all offer training opportunities, either regularly or on demand, as well as documentation hubs. These trainings can sometimes be facilitated through international organizations or bilateral agreements.
- **Identifying funding routes and mechanisms** to embed modelling in a country in the long-term.
- **Engaging with modelling communities to learn about best practices.** For example, the GAINS model user community now holds annual hybrid meetings where experiences are shared from around the world, while the LEAP-IBC model has a specific community forum where users can share experiences.

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Useful sources of information

An invaluable source of air pollution related information is the web-portal State of Global Air (*https://www.stateofglobalair.org/*), which offers historical time series data at the national scale on air pollution and related health effects.

The United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP) report highlights the need to accelerate progress towards the SDGs. UN ESCAP (2022). Asia and the Pacific SDG Progress Report (2022).

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The GAINS model is accessible through the internet at the International Institute for Applied Systems Analysis (IIASA): *http://gains.iiasa.ac.at/models/*

Evidence for statements relating air pollution and asthma in the introduction above is given in: Anenberg, S.C., Henze, D.K., Tinney, V., Kinney, P.L., Raich, W., Fann, N. et al. (2018). Estimates of the global burden of ambient $PM_{2.5}$, ozone, and NO2 on asthma incidence and emergency room visits. Environmental Health Perspectives 126 (10). 107004. DOI:10.1289/EHP3766

The CIAM under the LRTAP Convention of the UNECE is described here:
https://iiasa.ac.at/projects/integrated-assessment-modelling-for-negotiations-under-convention-on-long-range

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Glossary

ASEAN	Association of Southeast Asian Nations
BenMap	Environmental Benefits Mapping and Analysis Program
BRT	Bus Rapid Transit
CCAC	Climate and Clean Air Coalition
CLE scenario	Current Legislation scenario. A GAINS model scenario that reflects current policies, implemented or agreed as legislation, to control the emissions of air pollutants or GHGs
Cost of action	The costs for taking mitigating action, such as deploying additional technologies to reduce emissions
Cost of inaction	The monetized value of the (potentially) foregone benefits associated with an action (i.e. a policy intervention leading to a reduction of emissions)
Net cost of inaction	The cost of inaction, minus the cost of action
CTM	Chemical transport model
EMEP model	a particular chemical transport model developed by the European Monitoring and Evaluation Programme.
EMEP-EEA guide	Air pollutant emission inventory guidebook 2019 of the European Environment Agency
FAIR data principles	The FAIR (Findable, Accessible, Interoperable, Reusable) Guiding Principles for scientific data management and stewardship
GAINS	Greenhouse Gas Air Pollution INteractions and Synergies model, an integrated assessement model of air pollution and the emissions of GHGs developed and operated by IIASA.
GDP	Gross domestic product
GEOS-Chem	a particular chemical transport model developed by the NASA Global Modeling and Assimilation Office
GHG	Greenhouse Gas
GIS	Geographic Information System
GISS	a particular model of the atmosphere and the earth's climate developed by the NASA Goddard Institute for Space Studies
IIASA	International Institute for Applied Systems Analysis
LEAP	Low Emissions Analysis Platform
LPG	Liquified Petroleum Gas
MTFR scenario	Maximum Technically Feasible Reduction scenario. This represents the lowest impact scenario that can be achieved through the use of technical emission control equipment.

NH_3	Ammonia, an air pollutant emitted primarily in the agriculture sector
NO_x	Nitrogen oxides
OECD	Organisation for Economic Co-operation and Development
$PM_{2.5}$	Fine particulate matter with diameter of 2.5 micrometers or less. $PM_{2.5}$ is emitted directly ('primary $PM_{2.5}$'), but also forms by chemical reactions of precursor gases in the atmosphere. These precursors include SO_2, NO_x, NH_3, and VOC
QALY	Quality Adjusted Life Years
RFM	Reduced-form model. A simplified and efficient computer model which exhibits, in some essential sense, a similar behaviour as a more complex model that is computationally more expensive. The term is often used in the context of calculating pollution levels from emissions quickly for policy applications.
SEI	Stockholm Environment Institute
SO_2	Sulfur dioxide
CIAM (EMEP)	The Centre for Integrated Assessment Modelling - CIAM (EMEP)
VOC	(non-methane) volatile organic compounds
VSL	Value of statistical life
WHO	World Health Organization
WTP	Willingness to pay. A method for determining, e.g. the value of statistical life or a life year lost.

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