AIR QUALITY IN ASIA

WHY IS IT IMPORTANT, AND WHAT CAN WE DO?

1. KEY POLLUTANTS AND POLLUTION SOURCES

Air pollution has been an important scientific and political topic for some time. Despite this importance, air pollution continues to be one of the major environmental and societal challenges. This brochure gives an outline of the sources of air pollution in Asia, the impacts of air pollution on health and the environment, and the challenges and opportunities to deliver improvements in air quality, which would bring health and quality of life benefits for people throughout Asia.

HOW DOES ADB SUPPORT AIR QUALITY IMPROVEMENTS?

The Asian Development Bank (ADB) is committed to supporting Developing Member Countries to deliver long term, sustainable improvements in air quality. We do this through Technical Assistance programs, and provision of Policy-Based Loans and Results-Based Loans. ADB has invested $2.5 billion to support air quality improvements throughout the Greater Beijing–Tianjin–Hebei region of northeast People's Republic of China (PRC). ADB is currently investing over $200 million in improving air quality in Ulaanbaatar, Mongolia.

Densely populated urban areas and industrialized zones typically experience the highest levels of most air pollutants. The exceptions are ozone and ammonia, which are often higher in rural areas.

In order to understand how air pollution in Asia is formed, we need robust information on the emissions of air pollutants, and the substances that form air pollution in the atmosphere, at local, regional and global scales. Most of the air pollution experienced by individuals comes from sources in the local area or region. However, air pollution can travel longer distances, in some cases across national borders, depending on atmospheric conditions. For example, urban air pollution episodes can be can be caused by dust and airborne particulate matter from remote areas such as deserts. Regional sources like crop burning and wildfires can also cause increases in particulate matter concentrations.

THE KEY AIR POLLUTANTS THAT COULD AFFECT THE ENVIRONMENT AND HEALTH ARE:

Fine particulate matter ($PM_{2.5}$) is also referred to as "particulates" or "fine particles". The term $PM_{2.5}$ refers to tiny particles of solid or liquid with a diameter of 2.5 microns or less suspended in the air. $PM_{2.5}$ can enter the respiratory system and is linked to a range of adverse effects on respiratory and cardiovascular health. The main sources of $PM_{2.5}$ are activities such as the use of fossil fuels in vehicles, power stations, agriculture, combustion in the home and in industrial processes, as well as wind-blown dust from construction and agriculture. $PM_{2.5}$ can also be formed as a secondary pollutant due to reactions between other chemicals in the atmosphere. Exposure to $PM_{2.5}$ is linked with a range of respiratory and other health impacts – see section 2.

Black carbon, or soot, is part of $PM_{2.5}$. Black carbon is formed when fossil fuels, wood and other fuels are burned incompletely. In the atmosphere, black carbon has negative implications for both human health and the global climate. As a component of $PM_{2.5}$, inhalation of black carbon is associated with a range of health problems.

Nitrogen oxides (NO_x), and in particular nitrogen dioxide (NO_2), are produced from combustion of fuels including gasoline, diesel, fuel oil, coal, wood and natural gas at high temperatures. Nitrogen dioxide can sometimes be observed as a dome of brown haze over polluted cities, or downwind of polluted cities. The most prominent sources of oxides of nitrogen are internal combustion engines burning fossil fuels such as those found in vehicles and diesel generators, as well as all other kinds of combustion including power stations, home cooking and heating, and industrial processes. Exposure to nitrogen dioxide is linked to respiratory disease, and NO_x also has adverse effects on agriculture and natural ecosystems both directly and due to its role in forming ozone at ground level.

Sulfur oxides (SO_x) and in particular sulphur dioxide (SO2): Coal and liquid fuels often contain sulphur. The combustion of these fuels generates sulphur dioxide. This is a major cause for concern in the use of coal and oil as power sources. Exposure to sulphur dioxide at high levels can affect respiratory health, and acid deposition derived from sulphur dioxide also has adverse effects on agriculture and natural ecosystems.

Ozone (O_3) is generally not emitted directly to the atmosphere. Instead, it is formed in the atmosphere due to the interaction of sunlight with "precursor" substances, principally oxides of nitrogen and volatile organic compounds. Because this process takes time, ozone levels are typically highest in the areas downwind of major cities and industrial areas. While ozone is beneficial at high altitudes in the atmosphere, at ground level it is linked to respiratory disease and symptoms, and can also affect plant health.

Carbon monoxide (CO) results from the incomplete combustion of fuels. Sources include road vehicles, heating, the use of coal, charcoal, oil or gas fuels to generate electricity and heat, biomass burning, waste disposal and tobacco smoke. As well as human-made emissions, natural sources include the decay of organic matter (plants and animals), volcanic eruptions, and forest fires. Natural sources account for approximately 40% of global CO. The remaining 60% of global CO is from human activities. Exposure to high levels of CO in the environment can affect human health, although this is more commonly a problem resulting from poorly controlled indoor fuel burning.

Volatile organic compounds (VOCs) are emitted by human activity. The incomplete combustion of fuel, evaporation of fuel and solvents, biomass burning, and some industrial processes are the main sources of VOC. Vegetation can also emit a wide range of different types of VOCs. VOCs take part in photochemical reactions to produce secondary pollutants, such as low-level ozone, and can occasionally be directly toxic to people. Alkanes, alkenes, esters, alcohols, and acids are the most common VOCs of human origin.

Ammonia (NH_3) is produced from natural and human-made sources, including agriculture and waste management. Ammonia is not normally directly harmful to people, but can affect natural ecosystems, both directly and by contributing to acid and nitrogen deposition. Ammonia also plays an important role in the formation of secondary particulate matter in the atmosphere.

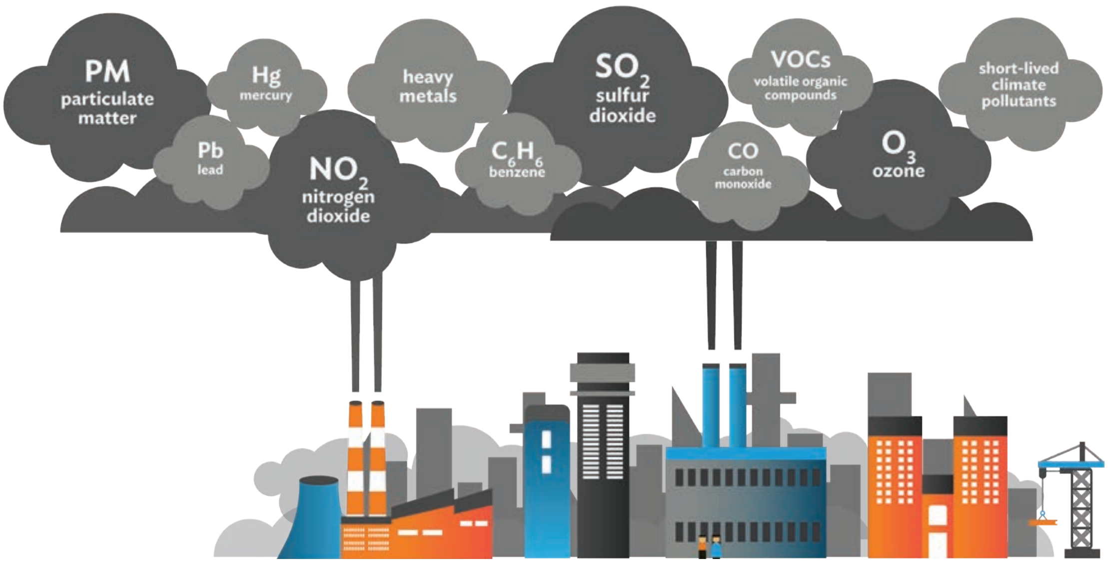
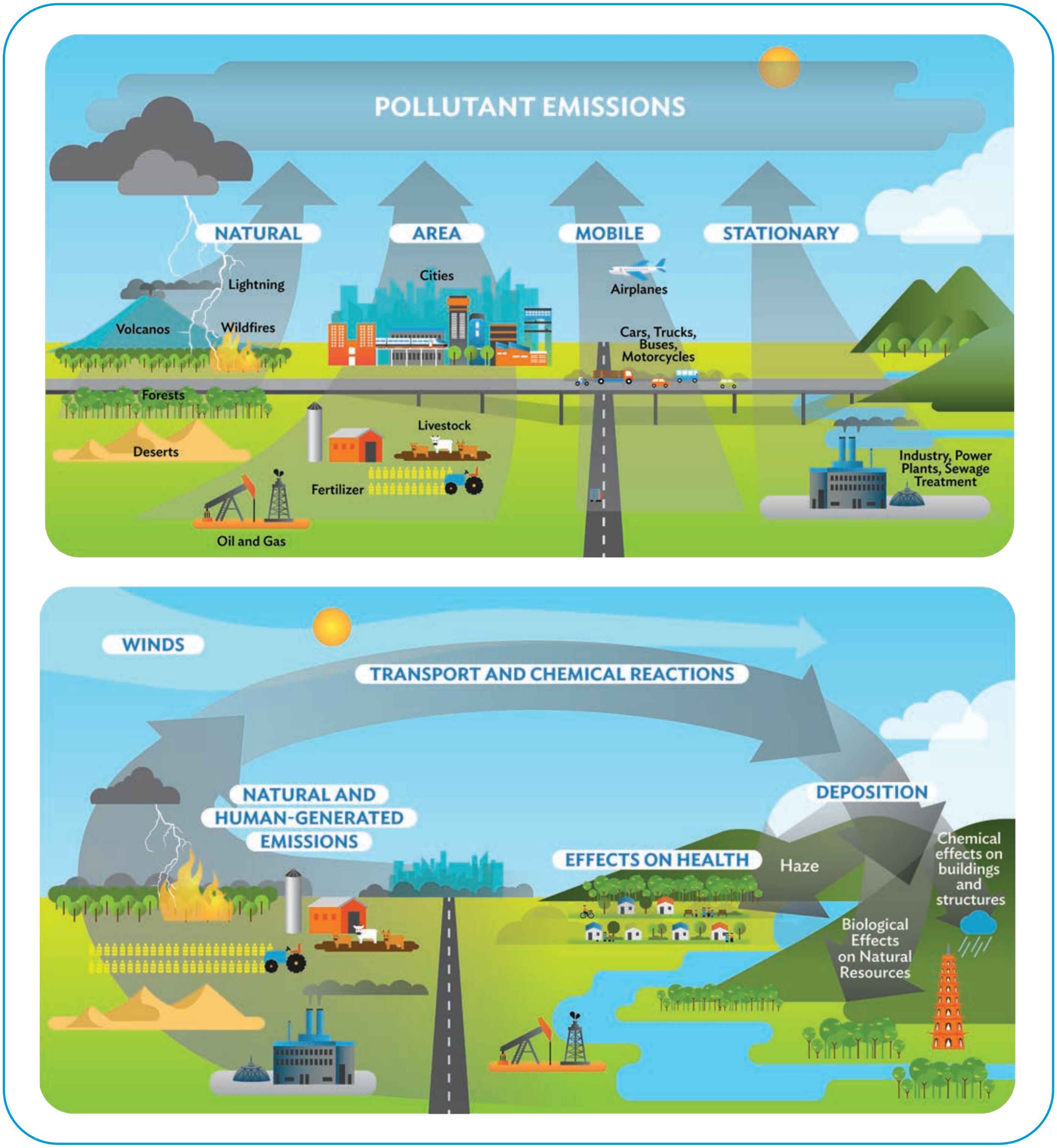


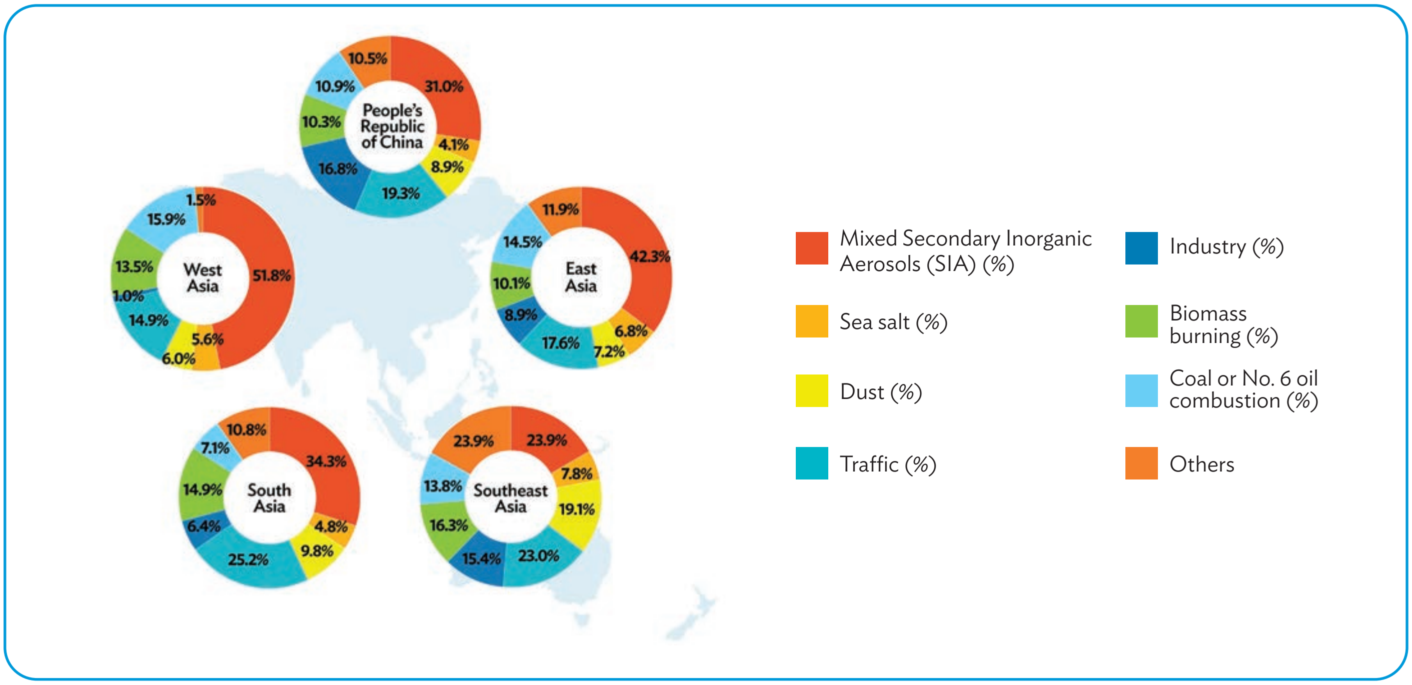
Figure 1: Sources, Pathways and Effects of Air Pollution



Source: https://www.nps.gov/subjects/air/sources.htm

A clear understanding of the contributions of different sources to levels of pollutants in the air helps to tackle adequately these sources and then to implement the most efficient measures. The variation in sources of $PM_{2.5}$ in different regions in Asia is a good illustration of the diversity of sources of air pollution.

Figure 2: Source Contributions to $PM_{2.5}$ Emissions

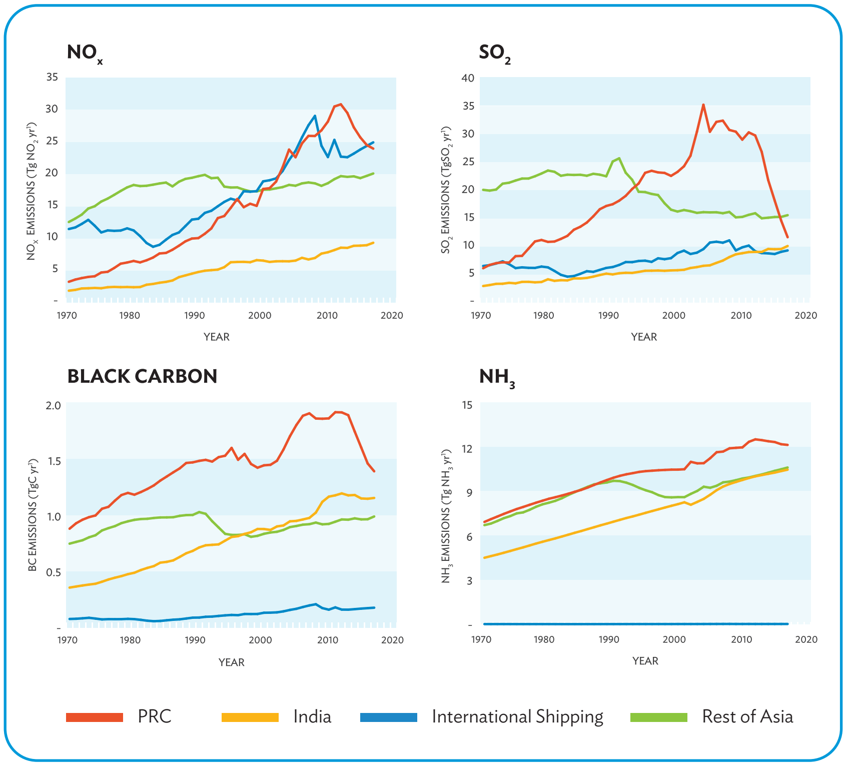


Source: Hopke et al. (2020).

Emissions of primary pollutants from human activity have increased in Asia over the past 50 years (e.g. McDuffie et al., 2020, Kurokawa and Ohara, 2020; Sadavarte et al., 2019), mainly driven by economic growth. Increases in emissions between 2004 and 2011 were largely driven by increasing domestic consumption, but export-related emission growth was also notable.

In the last decade, emissions of most pollutants in the PRC started to decrease. The downward trend in NO_x emissions from the PRC since 2011 has been mainly due to emission control measures in the power sector (Liu et al., 2017). A case study illustrating how the PRC has decoupled air pollution from economic growth through appropriate investment and control is provided in section 6.2. In contrast, in the rest of Asia, emissions continued to increase, although some studies indicate that the growth of emissions of air pollutants in more recent years is beginning to slow down (Meng et al., 2019).

Figure 3: Trends in emissions of key air pollutants from 1970 to 2017



PRC=People's Republic of China.

Source: McDuffie et al., 2020.

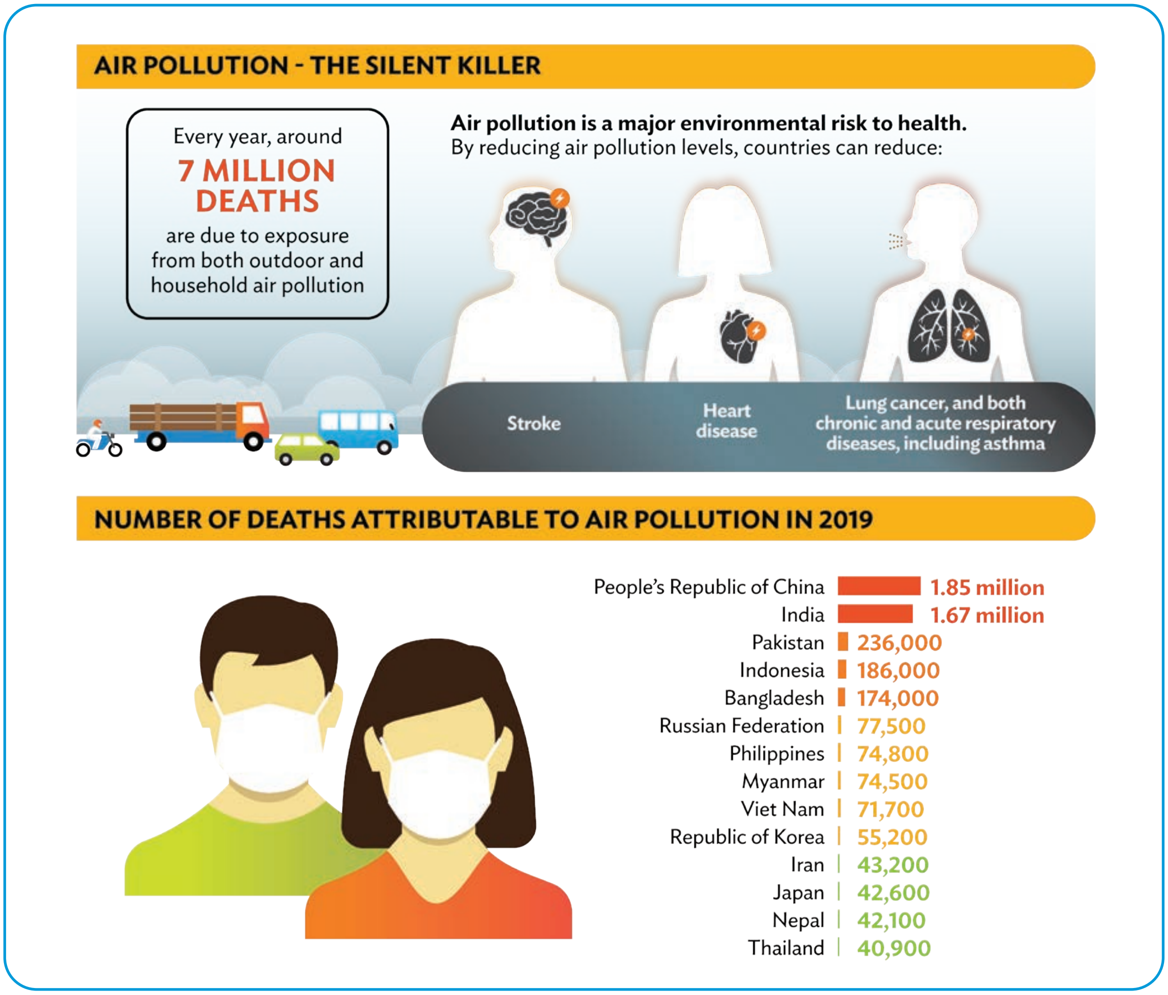
2. HEALTH AND ECONOMIC IMPACTS OF AIR POLLUTION

Air pollution is a factor in causing and making worse a range of diseases. Air pollution has been linked to asthma, cancer, pulmonary disease and heart disease. The International Agency for Research on Cancer classifies both air pollution, and the particulate matter in outdoor air, as carcinogenic to humans.

The World Health Organization continues to confirm that air pollution is an increasingly important risk factor for non-communicable diseases. Air pollution is recognized as the main environmental contributor to the burden of disease. Air pollution was found to be the second-largest factor affecting the risk of noncommunicable diseases at a global level, after tobacco smoking (Prüss-Ustün et al., 2019). Air pollution is now the largest cause of non-communicable diseases in many countries and regions such as in Southeast Asia. Evidence for the range and severity of these effects continues to emerge.

Approximately 4 billion people (92%) in the Asia and Pacific region experience levels of air pollution that present a significant risk to their health. In 2019, four Asian countries were among the top 10 countries with the highest population-weighted average exposure to $PM_{2.5}$ (India was the first, followed by Nepal) (State of Global Air 2020). As a result, air pollution in Asia and the Pacific region is estimated to be responsible for 4 million early deaths every year.

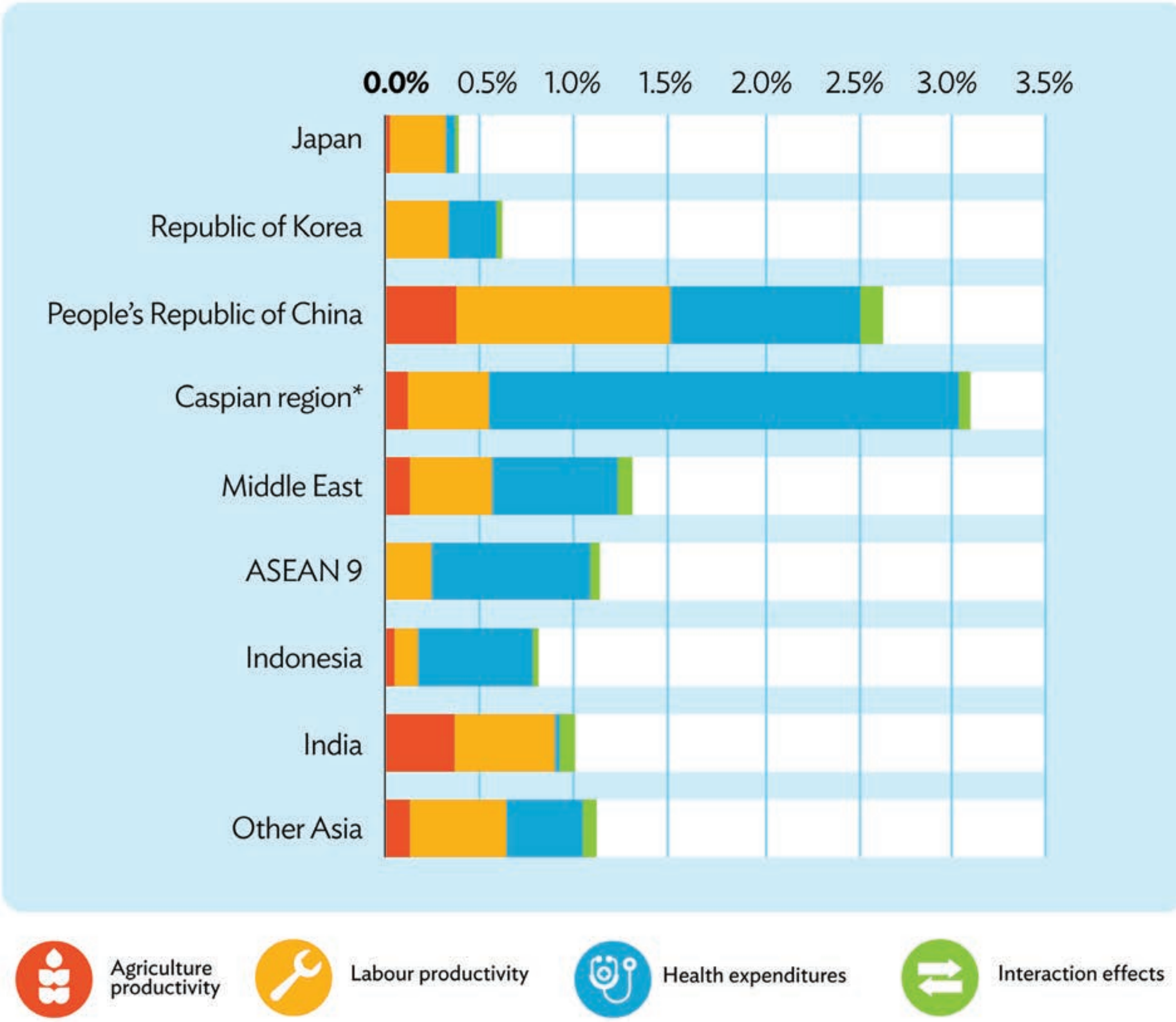
Figure 4: The Global Impact of Air Pollution on Health (2019)



Source: Health Effects Institute. 2020. State of Global Air 2020; Global Burden of Disease Study 2019. IHME, 2020.

Air pollution has a substantial effect on Asian economies, with air pollution estimated by the Organisation for Economic Co-operation and Development (OECD) to account for a reduction of 1% to 2.5% in GDP across different economies in Asia by 2060. These costs come mainly from reduced productivity, and increased health-care costs. For context, the economic burden of smoking in the PRC is estimated to be about 0.7% of GDP (Ekpu and Brown, 2015). Differences in projected GDP losses arise from factors such as the cost of health care, and the age profile of different populations.

Figure 5: Projected Impact of Air Pollution on GDP in 2060



*Caspian region: includes parts of Azerbaijan, Kazakhstan, Russia, Turkmenistan and Iran
ASEAN9: The 9 largest members of the Association of Southeast Asian Nations (ASEAN) region.

Source: OECD, 2016

3. AIR POLLUTION AND COVID-19

The severity of the COVID-19 pandemic has been increased by air pollution. Conversely, society responses to the pandemic have also had an effect on air pollution.

Current and past exposure to air pollution could plausibly affect individual responses to the COVID-19 virus, potentially making individuals more susceptible to the virus. It is difficult to be confident, but a preliminary estimate by Pozzer et al. (2020) suggests that particulate air pollution accounted for just over a quarter (27%) of COVID-19 mortality in East Asia with lower contributions of 15% in South Asia and 8% of COVID-19 mortality in West Asia. This means that the impacts of the COVID-19 pandemic would have been substantially lower if high air pollution was less widespread in Asia. This only adds to the health and economic burdens of air pollution shown in Figures 4 and 5, and further emphasizes the importance of taking action to improve air quality.

At the same time, during the global COVID-19 pandemic in 2020 and 2021, air pollution levels dropped significantly in response to reductions in travel and economic activity during lockdown situations. This has resulted in some dramatic improvements in air quality. As economies restart, air pollution levels are returning toward pre-lockdown levels.

Figure 6: Haze Shrouding New Delhi's India Gate Before Lockdown, and Clear Skies During Lockdown

The India Gate war memorial in New Delhi, India, on 17 October 2019 and on 8 April 2020, after a 21-day nationwide lockdown.

Source: Anushree Fadnavis/Adnan Abidi/Reuters. https://www.insider.com/before-after-photos-show-less-air-pollution-during-pandemic-lockdown#before-in-2019-cnn-cited-dangerous-levels-of-pollution-in-new-delhi-describing-indias-capital-as-shrouded-in-a-toxic-throat-searing-cloud-of-brown-smog-7.

The Centre for Research and Energy and Clean Air (2020) analyzed air pollution data to estimate how improve air quality has impacted on people suffering from pre-existing conditions, such as asthma, diabetes and heart disease. This study indicated that up to **11,000 early deaths have been avoided due to improved air quality** across Europe during the first 6 months of the pandemic.

Similarly, in the PRC, the two months of pollution reduction during the initial COVID-19 lockdown is estimated to have **saved 4,100 children under 5, and 73,000 adults over 70** (G-FEED Group, 2020). Sharma et al. (2020) estimated that the annual death toll in India could reduce by **650,000** if the decrease in air pollution levels during the country's lockdown were maintained (Sharma et al., 2020). These striking figures underline that major changes in activity such as those imposed during the COVID-19 epidemic can result in substantial improvements in air quality, and as a result, substantial improvements in health with associated economic and societal benefits.

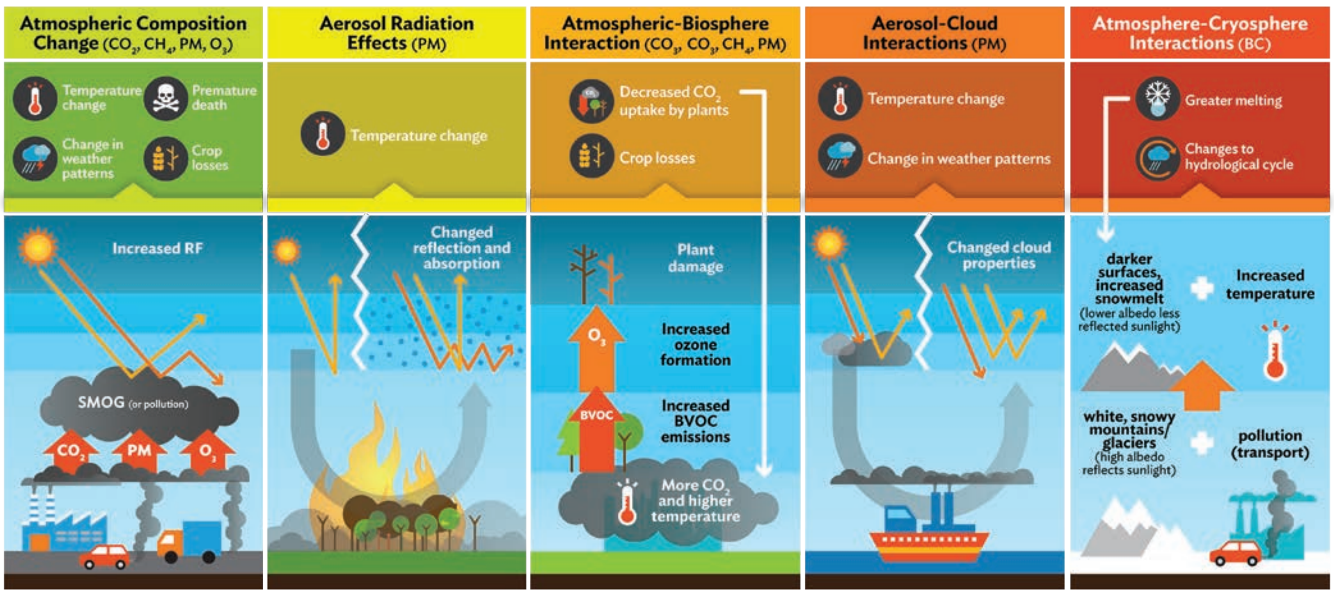
4. THE LINKS BETWEEN AIR QUALITY AND CLIMATE CHANGE

The causes of climate change and air pollution are closely linked. As a result, it is often possible to take steps which address both environmental challenges. The main sources of both air pollutants and greenhouse gases (GHGs) include combustion processes (for example, domestic, commercial and industrial heating, electricity generation; transport; and agriculture). Additionally, some air pollutants also influence global and regional climates (Climate and Clean Air Coalition, 2019). Examples include:

- Deposition of air pollution can darken snow, resulting in increased heat absorption and shortening the snow season.
- Monsoon rains are a crucial source of water for agriculture. Increased air pollution in the monsoon regions can result in changes to long-term rainfall patterns. The impacts of air pollution on the Asian monsoon are complex and still subject to uncertainties.
- Some air pollutants - notably, black carbon (or soot) and ozone – contribute to global warming through their action as short-lived climate pollutants (SLCPs).

These interactions are illustrated in Figure 7.

Figure 7: The interactions between air pollution and climate change



BVOC=Biogenic Volatile Organic Compounds, RF=radiofrequency

Source: von Schneidemesser et al., 2015.

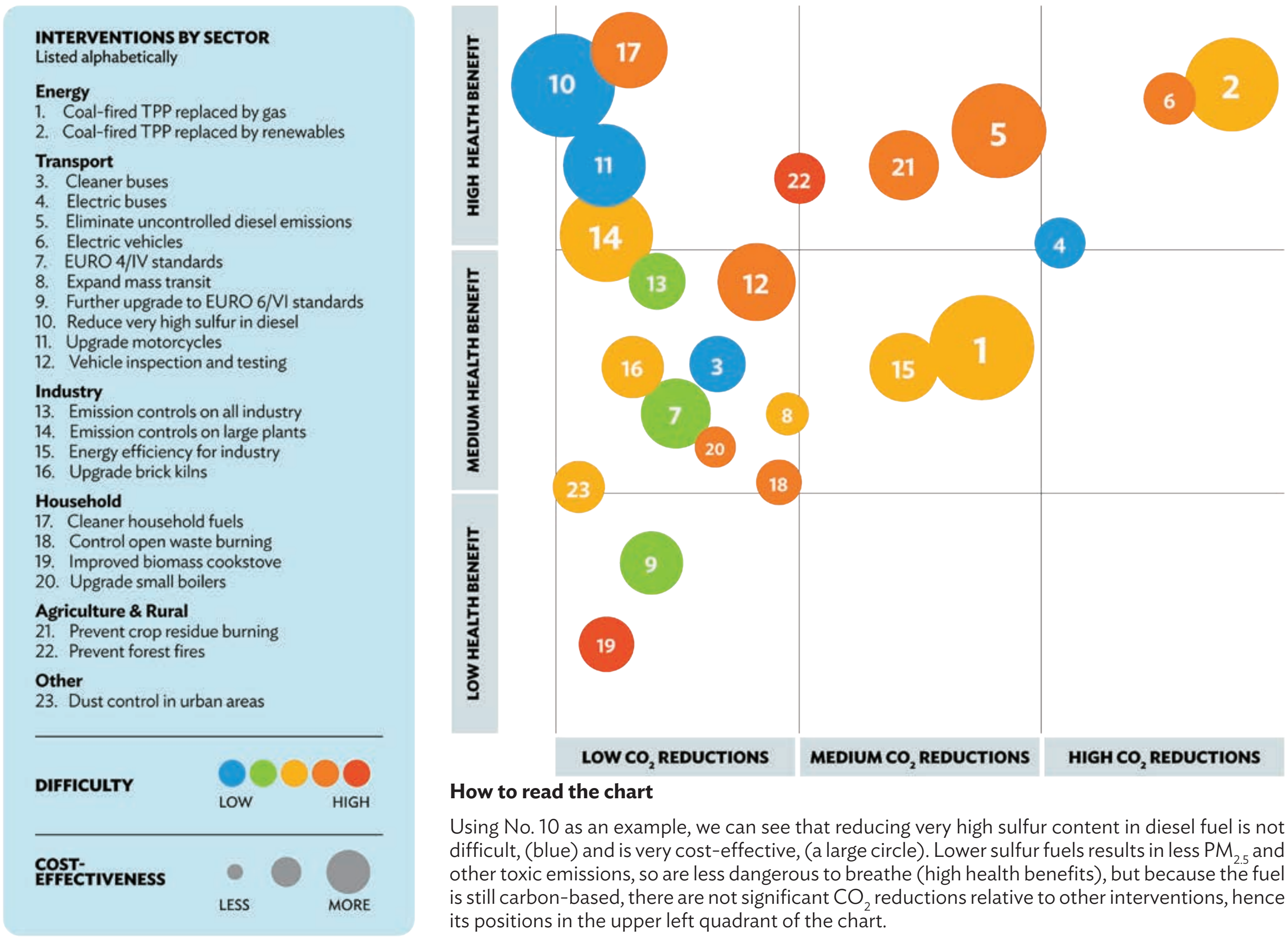
Consequently, policies and measures which simultaneously tackle air pollution and climate change are particularly valuable. Such policies can provide multiple benefits, especially those that reduce emissions of SLCPs or black carbon, or which focus on reducing ground-level ozone in the atmosphere. Such policies can complement other initiatives to slow down effects on the global climate, for example by reducing emissions of carbon dioxide and methane.

5. SOLUTIONS FOR IMPROVING AIR QUALITY AND EXPECTED HEALTH AND ECONOMIC BENEFITS

Research being carried out for ADB has highlighted a very wide range of measures for improving air quality and delivering associated health and economic benefits. These are set out in Appendix 1.

The Global Alliance on Health and Pollution has produced a useful analysis of potential measures to deliver improvements in both air quality and GHG (Figure 8). This shows that measures such as moving to electric vehicles and replacement of fossil fuels with renewables can be effective in improving both air quality and GHG.

Figure 8: Interactions Between Air Quality and Climate Improvement Measures



How to read the chart

Using No. 10 as an example, we can see that reducing very high sulfur content in diesel fuel is not difficult, (blue) and is very cost-effective, (a large circle). Lower sulfur fuels results in less $PM_{2.5}$ and other toxic emissions, so are less dangerous to breathe (high health benefits), but because the fuel is still carbon-based, there are not significant CO_2 reductions relative to other interventions, hence its positions in the upper left quadrant of the chart.

Source: GAHP, 2020.

This chart is based on experience and professional judgment to provide an indication of the general magnitude of climate and health benefits and costs (GAHP, 2020).

- **Health benefits.** $PM_{2.5}$ levels are used as proxy. Low: estimated reduction in average ambient $PM_{2.5}$ concentrations of less than about 1%. Medium: reduction about 1 to 5%. High: above 5 %.
- **Climate benefits.** Metric is tons of CO_2 equivalent reduced: Low: estimated to be less than 0.1% of total CO_2 releases for the urban area. Medium: up to about 2%. High: above 2%.
- **Cost.** This is considered as the direct cost that the implementing agency has to provide in the context of a major city. Low: estimated costs over 5 year less than $5 million. Medium: up to $100 million. High: above $100 million.

More information on these measures and the information summarized in Figure 8 is available at:
https://gahp.net/wp-content/uploads/2020/06/AirPollutionReport_6_22_Final.pdf

A wide range of funding mechanisms are available to support the implementation of air quality solutions. These include the use of fees and charges, fiscal mechanisms (e.g. subsidies or tax incentives), market mechanisms (e.g. waste management contracts that incentivize segregation of waste at source) and ensuring that investments in public transport or climate mitigation also deliver air quality benefits. External financial support may be available from development partners to fill any funding gap.

The following organizations are active in working to understand the health and environmental impacts of air pollution, and to improve air quality throughout Asia.

Figure 9: Examples of organizations active in improving air quality in Asia

Intergovernmental Agencies

- UNEP (Nairobi) The United Nations Environment Programme (UNEP)
- The Asia Pacific Clean Air Partnership (APCAP)
- The World Health Organization (WHO)
- The World Resources Institute (WRI)
- C40 Cities
- The International Centre for Integrated Mountain Development (ICIMOD)
- The Association of Southeast Asian Nations (ASEAN)
- South Asia Co-operative Environment Programme (SACEP)
- Malé Declaration on Control and Prevention of Air Pollution and its likely Transboundary Effects for South Asia

Development Partners

- Asian Development Bank (ADB)
- World Bank Group
- European Bank for Reconstruction and Development (EBRD)
- The Clean Air Fund
- Gesellschaft für Internationale Zusammenarbeit (GIZ) (Germany)
- Swedish International Development Cooperation Agency
- Agence Française de Développement (AFD)

Research and Data Organizations

- Stockholm Environment Institute (SEI)
- The Asian Institute of Technology (AIT)
- OpenAQ

Non-Governmental organizations

- Clean Air Asia
- Pure Earth
- Environmental Defense Fund (EDF)
- Environment and Security Center of Mongolia (ESCM)
- Sustainable Development Policy Institute (SDPI)
- Global Alliance on Health and Pollution (GAHP)
- Climate and Clean Air Coalition

6. SUCCESS STORIES

6.1. City-scale initiatives to improve air quality

1 Dhaka, Bangladesh: Two-stroke engines ban (GAHP, 2020)

In 2002, a **40% reduction in particulates** in Dhaka city center was reported following a ban on two-stroke three-wheeler "baby taxis".

Following this, all two-stroke engine vehicles were banned from Dhaka in December 2002. This resulted in improvements in levels of fine PM and black carbon in Dhaka.

2 Low Emission Zones in Europe

Many cities in Europe (Lisbon, Madrid, Oslo, etc.) have used Low Emission Zones in their city center in order to reduce air pollutants concentrations such as $PM_{2.5}$ and NO_x related to traffic. Due to the encountered success, the city of London has decided to go further by implementing Ultra Low Emission Zone. It was launched in April 2019.

Results after the initial 6 months of operations are:

1. The average compliance rate was 77% in a 24-hour period
2. NO_x reduction of 36% in the central zone
3. NO_2 concentrations at roadside reduced by 29%
4. CO_2 emissions from road transport reduced 4%
5. None of the air quality monitoring stations located in the ULEZ have measured an increase in NO_2 since ULEZ introduction.
6. Introducing the ULEZ contributed to a reduction in traffic flow of between 3% and 9% compared to the previous year

In October 2021, the ULEZ area was extended to cover the whole area encompassed by the North and South Circular roads.

Photo source: https://www.evo.co.uk/advice/202337/ulez-explained-pictures

3 Kolkata (India): Renewable energy on transport (Electric buses & ferries, solar panel on bus depot)

The city has a significant air quality problem with $PM_{2.5}$ concentrations of 85.4 ug/m^3 in 2018 which exceeds the WHO recommended limit of 10 ug/m^3 eightfold. A long-term plan was adopted to electrify the ferries on the River Ganges, and to purchase 5 thousand electric buses by 2030. By 2030, it is estimated that the electric bus fleet will reduce CO_2 by about 200,000 tons a year while also delivering reduced emissions of $PM_{2.5}$ and other pollutants. The transport operator is planning to invest in solar roofing its bus depots together with solar battery storage which will further contribute toward decarbonizing the transport system and reducing emissions to air.

WHO, UN Environment and Climate & Clean Air Coalition: BreatheLife

4 Can Tho, Viet Nam: Clean air action plan

An ongoing program is under way to restricting personal transport while improving public transport. The use of biofuel is encouraged, along with increasing urban green coverage. Progress is tracked through continuous air quality monitoring, with one station located at a traffic gateway into the city.

https://breathelife2030.org/breathelifecity/canthovietnam/

5 Bogor, Indonesia: Clean air action plan

(https://breathelife2030.org/news/bogor-city-develops-clean-air-action-plan-intends-join-breathelife-network/)

The objective is to reduce SO_x, $PM_{2.5}$ and VOCs emissions:

- Transport: promotion of mass public transportation, cycling and walking; improving capacity for vehicle inspection and maintenance to reduce emissions to air; reducing emissions from stationary sources:
- Industrial: A wide range of measures are specified, focusing on industry (improving systems for emissions testing and monitoring compliance), improving solid waste collection systems to enable open burning of garbage to be reduced, and agriculture (banning the burning of rice straw residues while promoting more sustainable practices).

6 Singapore: Vehicle Emission Standards

https://www.nea.gov.sg/media/news/news/reducing-pollution-from-in-use-vehicles-to-achieve-better-air-quality

New petrol vehicles have been required to meet Euro 6 emission standards from September 2017. Similarly, new diesel vehicles have had to meet Euro VI limits since January 2018. These measures are expected to result in reductions of up to 55% of CO emissions, and 51% of hydrocarbon emissions.

7 Delhi, India: Clean buses

Over 10,000 electric and compressed natural gasbuses have been deployed since 2000 by private and public operators, resulting in up to 97% reduction in emissions compared to diesel buses (Kathuria, 2005).

8 Hong Kong, China: Cleaner buses

The franchised bus companies in Hong Kong, China have carried out a program to retrofit older Euro II and III emissions standard buses with Diesel Particulate Filters, where technically feasible. This was completed in 2010, and was forecast to reduce particulate emissions from these buses by over 80%. Additionally, the Government has set up Low Emission Zones along three transportation corridors in the Central District of Hong Kong, China. More recently, a program was implemented to further reduce emissions from franchised buses with selective catalytic reduction devices, and to procure six hybrid buses and 36 electric buses as a pilot program. The upgraded buses were targeted to achieve at least Euro IV emissions standard by 2017.

9 Shenzhen, the PRC: Electric buses

A total of 16,000 electric buses have been installed in Shenzhen, together with supporting charging infrastructure at 180 depots. Each bus cost more than $250,000, with up to 50% of the cost subsidized by national and local government. A 48% reduction in CO_2 emissions, and similar reductions in air pollutants, are expected from this investment.

10 Ha Noi, Viet Nam: Motorcycle pollution

https://vneconomictimes.com/article/society/motorbikes-not-cars-the-environmental-threat

The use of motorcycles in the center of Ha Noi will be banned from by 2030, following a vote by the Hanoi People's Council in 2018. The aim of this ban is to reduce air pollution and also make the city safer by reducing road accidents. This will be implemented by investing in improved public transportation in the city over a 12 year period. No-go areas for motorcycles will then be introduced in a phased way, to cover the entire inner city area by 2030. The city aims to provide access to public transportation within 500 meters of their home for 80% of city center residents.

11 Ulaanbaatar (Mongolia): Energy efficiency stoves / Air Quality Improvement Program / electricity tariff subsidy

Three projects are targeted toward the use of cleaner domestic fuels:

The Government of Mongolia introduced a program of subsidized, energy efficient stoves in Ulaanbaatar, distributing more than 100,000 stoves between 2011 and 2013 (Clean Cooking Alliance, 2015). It achieved a 65% reduction in particulate emissions. Through widespread adoption, ambient air pollutant concentrations could be reduced by 30%.

ADB has implemented a policy-based loan to support the Ulaanbaatar Air Quality Improvement Program. In Phase 1, less polluting fuels were made available, allowing the use of raw coal for domestic heating to end. In Phase 2, the implementation of relevant regulations and policies will be facilitated. The aim of this PBL is to reduce annual average ambient $PM_{2.5}$ concentrations in the city by 30% between 2019 and 2021.

The Air Pollution Action Plan 2017–2025 includes significant financial support for households in ger districts to use to use electric heating stoves as well as additional support for the transition to clean coal technologies. The Air Pollution Action Plan estimates over $200 million in government support for the roll-out of 2.5 kW electric household stoves in 130,000 households.

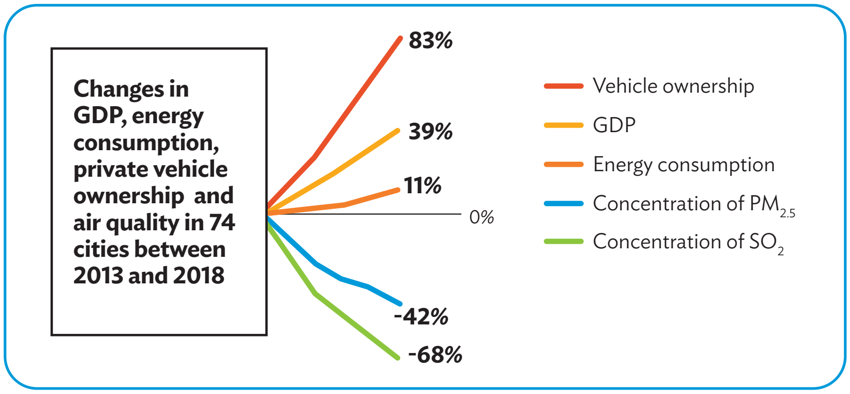
6.2. Country scale initiatives to improve air quality

12 The PRC: Air Quality Management

www.allaboutair.cn/uploads/soft/181114/Breakthroughs_ChinasPathtoCleanAir2013-2017.pdf

The PRC saw significant breakthroughs with the Path to Clean Air policy 2013-2017". This focused on: Science-based capacity building; control of key pollution sources; supporting measures; and inter-departmental coordination and cooperation. As a result, PRC has substantially reduced pollutant concentrations:

Figure 10: Economic development and improvement in air quality in the PRC (2013–2018) (MEE, 2019)



Source: Chinese Academy of Environmental Planning.

13 Bangladesh: Improved Fertilizer Application

The United States Agency for International Development (USAID) funded the Accelerating Agriculture Productivity Improvement project in Bangladesh. The project included 1.3 million farmers in 22 districts. The measures implemented included deep placement of urea to optimize nutrient uptake, alternate wetting and drying to reduce anaerobic decomposition in rice fields and soil management improvements for vegetables and high value crops. These measures were found to reduce unintended losses of nitrogen, with some farms showing a decrease in emissions of up to two-thirds.

14 Nepal: Clean Brick Initiative

https://www.icimod.org/initiative/about-air-pollution-solutions-initiative

https://www.ccacoalition.org/en/initiatives/bricks

This initiative enabled cleaner brick manufacturing technologies to be adopted within Government policy and by entrepreneurs. A key part of the program is to improve technical capacity in the design, manufacture, efficient operation, mechanization, and maintenance of energy-efficient brick kilns. Alongside this, the exposure of the workforce to air pollution is reduced by ameliorating their working conditions. These measures can reduce pollutant emissions by more than 90%. The initiative will share best practices with other countries in the region from Nepal and vice versa.

15 Malaysia: Financing options related to transport sector

Green technology financing scheme (GTFS 2.0) was introduced in Malaysia (effective 1 January 2019). It focuses on 3 categories of transport sectors: transport infrastructure, vehicles, and green fuels production.

Philippines and Thailand: Biodiesel

16 Philippines

The Philippines enacted the Biofuels Act in 2006 following which the blending of coco biodiesel or coconut methyl ester in petroleum diesel started in 2007. During the first year, a 1% blend was used which was subsequently increased to 2% after a year. It has remained at this since then but the plan is to increase the blend to 5% by 2021.

17 Thailand

Thailand is a major international producer of biodiesel. Thailand introduced an option for B2 (2% blend) biodiesel in 2008 which was subsequently increased to 7% in 2014 and intends to further increase the blend to 10% with a long-term target of 30% blend by 2025.

18 PRC: High-Efficiency Low-Emission (HELE) upgrade policy

Coal-fired power generation represents a substantial proportion of total electricity generation in the PRC. In order to secure ongoing reductions in CO_2 and air pollution emissions, the PRC is actively pursuing a HELE upgrade policy. This provides for the development of UltraSuperCritical (USC) plants to maintain and expand capacity, together with the retirement of older, less efficient units. More than 50% of large-scale projects under construction now consist of USC units. This policy is forecast to result in a 16% reduction in sector CO_2 emissions by 2040, despite an increase in electricity demand.

APPENDIX: MEASURES TO IMPROVE AIR QUALITY

Table A1: Measures to Address Domestic Sources of Air Pollution

Measure	Pollutant(s) targeted	Description
Improvements in fuel quality	PM, SO_x	• Preparation and separation of raw coal (including washing) • Regulating type of coal used in households • Enclosure of coal distribution and storage centers • Establishing a clean coal supply chain • Improved standards for the use of biomass fuel
Switching to cleaner fuels	PM, NO_x, SO_x,	• Regulating or eliminating the use of solid fuels and banning construction of new coal-fired boilers • Introducing / extending the use of natural gas, Liquefied Petroleum Gas, renewable or electric stoves and heating sources, or less polluting solid fuels (e.g. wood pellets) • Expanding the coverage of central heating systems in homes and businesses or use of district heating systems
Improvements in energy efficiency	PM, NO_x, SO_x	• Replacing old and inefficient energy devices with new, more efficient boilers and stoves • Improvement of building fabric: Insulation of walls, ceilings and windows and draft reduction • Good housekeeping / servicing of existing boilers / stoves • Installation and use of climatic controls • Use of eco-labelled, efficient devices and appliances • Energy efficient lighting
Installation of end of pipe technologies	PM, NO_x	• Filters in household (kitchen e.g. rangehoods) • Catalytic insert for stoves (such inserts do not work on fireplaces because the flue gas temperature too low, or for mineral fuels because the catalyst clogs or is poisoned by sulfur and/or heavy metals). Use on stoves has mixed success but essentially needs to be built in to appliance, because the stack temperature is typically too low for the catalyst to operate effectively. • Cyclones / de-dusters / etc. for boilers
Promotion of clean operation and energy efficient behavior	PM, NO_x, SO_x	• Communication and engagement, i.e. provision of information, training, personal advice, demonstrations, goal-setting • Provision of information tools, e.g. meters, temperature gauges, thermometers • Standby switches, turning off lights
Extraction/ Indoor air quality	PM, NO_x, SO_x	• Combustion gas extraction (stove chimney, hoods over cooking stoves) • Use or building controls to require minimum ventilation or extraction requirements • Minimum standards for construction of such chimneys (i) to protect user of appliance from combustion products, (ii) to protect chimney and building from fire, (iii) to mitigate impact on external environment

Source: TA-9608 REG: Strengthening Knowledge and Actions for Air Quality Improvement. Review of technology and policy options for improving air quality. ADB.

Table A2: Measures to Address Transportation Sources of Air Pollution

Measure	Pollutant(s) targeted	Measure description
Emissions standards and inspections for road vehicles	PM, NO_x, (SO_2)	• Establishing testing and vehicle maintenance centers • Roadside emissions testing • Awareness campaigns • Improving fuel quality
Promote the use of low emission vehicles and reducing demand	PM, NO_x, (SO_2)	• Upgrading to newer, cleaner conventional fuelled vehicles, or switching to cleaner conventional fuels (e.g. from diesel to petrol) • Promotion of renewable fuels such as ethanol and biodiesel • Switching to mixed power trains (e.g. hybrids) • Switching to unconventional fuels (e.g. to electric, hydrogen or biomethane powered vehicles) • Retro-fitting existing vehicles (e.g. fly-wheels on buses) • Active travel (e.g. walking and cycling) • Optimization of logistics / deliveries • Adoption of urban mobility plans to regulate and streamline commuting • Car-sharing or car clubs • Encouraging flexible working • Vehicle population control and changes to parking provision in city center
Improved public transport and traffic changes	PM, NO_x, (SO_2)	• Greater provision and use of public transport (e.g. trolley-buses, buses, trains, metros, etc.) • Optimization of urban planning and layout • Improvements to junctions and speed controls • Bypass construction • 'tidal lanes' and widening of roads • Intelligent traffic control systems and traffic management
Fugitive Dust control	PM	• Street sweeping • Paved roads • Dust sprays • Requirements for dust management plans • Control of construction activities and sites
Electric transport	PM, NO_x, (SO_2)	• Requires electrical charging infrastructure • Requires reliable electrical supply • May be offsets with emissions from electricity generation
Eliminate 2-stroke engines	PM, NO_x, (SO_2)	• Introducing technological solutions to minimize emissions • Implementation of stringent regulations • Provision of financial incentives to discourage usage
Integrate land-use and transport planning	PM, NO_x, (SO_2)	• Promotion of mix use development • Discourage sprawl • Encourage smart urban growth • Development of mass transit initiatives/BRT-bus rapid transit systems • Identification and development of feeder routes along the transport corridors. • Transit Development Management measures to be explored and implemented
Financing options	PM, NO_x, (SO_2)	• Provision of tax incentives for renewing public vehicles registration • Offering cash for older public vehicles to get them off the roads • Ensuring credit for purchasing new public vehicles • liberalizing the trade of new vehicles for public use • Optimize financing options especially micro-financing according to market dynamics • Explore funds like multilateral climate funds, bilateral funds, carbon markets

Table A2 continued

Measure	Pollutant(s) targeted	Measure description
Emissions testing	PM, NO_x, (SO_2)	• Establish roadside testing facility. • Install specialized equipment remotely measures tailpipe emissions from vehicles passing a given point. • Introduce awareness campaigns to encourage users to conduct testing (e.g. highlighting the potential safety improvements and cost savings)
Improve fuel quality	PM, NO_x, (SO_2)	• Upgradation to better quality fuels • Coupling clean fuels with clean engine technologies • Investments by fuel industry as well as auto industry
Alternative fuels	PM, NO_x, (SO_2) CO_2	• Explore and usage of alternate fuels-Ethanol, compressed natural gas, Propane, hydrogen, bid diesel, electricity etc • Regulatory and financial support for alternative fuels
Secondhand vehicles and engines	PM, NO_x, (SO_2)	• Monitor and record share of secondhand cars • Ensure meeting of “emission standards” and “safety standards” • In place regulations for managing vehicles import
Vehicle replacement	PM, NO_x, (SO_2)	• Replacement of high emitting vehicles through different schemes • Optimal balance between “financial benefits” and “environmental benefits” required
Low emission zones	PM, NO_x, (SO_2)	• Limiting vehicles entry to a zone • Improvement in vehicle emissions legislation • Usage of technology for enforcement
Central area congestion charging zones	PM, NO_x, (SO_2)	• Limiting vehicles entry to a smaller targeted zone • Usage of technology for enforcement • Alternative modes of transport may be needed • Explore co-benefits with improving journey times
Policies to promote biking and walking	PM, NO_x, (SO_2) CO_2	• Promotion of mix use development • Discourage sprawl • Encourage smart urban growth • Requires investment in safe cycling routes and infrastructure • Explore health and climate co-benefits
Landscape and planting	PM, NO_x, (SO_2) CO_2	• Requires sufficient space for urban planting • Careful planning required to avoid causing increased impacts • Explore co-benefits for climate and urban livability
Transit oriented development	PM, NO_x, (SO_2) CO_2	• Promotion of mix use development • Discourage sprawl • Encourage smart urban growth • Development of mass transit initiatives/BRT-bus rapid transit systems • Identification and development of feeder routes along the transport corridors. • Transit Development Management measures to be explored and implemented
Park & Ride	PM, NO_x, (SO_2) CO_2	• Requires suitable, attractive public transport systems • Requires suitable secure parking areas • Strengthen parking controls in central areas
Parking controls	PM, NO_x, (SO_2)	• Encourages use of alternative modes of transport • Alternative modes of transport may be needed • Requires clear signage and enforcement • May be co-benefits for reduced congestion

Source: TA-9608 REG: Strengthening Knowledge and Actions for Air Quality Improvement. Review of technology and policy options for improving air quality. ADB.

Table A3: Measures to Address Waste Sector Sources of Air Pollution

Measure	Pollutant(s) targeted	Measure description
Solid waste management	NO_x, NO_2, PM, SO_2, CO, PAHs, VOCs, heavy metals, dioxins and furans CH_4	• Development of appropriate waste collection, recycling and disposal systems and infrastructure • Collection and treatment of wastewater • Capture / recovery of waste gases (e.g. from landfill or wastewater treatment plant), with flaring or utilization (e.g. anaerobic digestion) • Reduction or recycling of waste • Diversion of organic waste (either domestic or industrial) from landfill to treatment using anaerobic digestion, composting or incineration

Source: TA-9608 REG: Strengthening Knowledge and Actions for Air Quality Improvement. Review of technology and policy options for improving air quality. ADB.

Table A4: Measures to Address Agriculture Sector Sources of Air Pollution

Measure	Pollutant(s) targeted	Measure description
Managing agricultural crop residues	PM, NO_x, SO_2, CH_4, VOC	• Ban the outdoor burning of agricultural and other waste streams in urban areas and surrounding areas • Use satellite remote-sensing technology to identify the areas where burning is taking place, and to monitor burning activities • Strategies to properly manage harvest residue, e.g. use of alternatives such as hay silage for cattle or use of manure or harvest residues to improve soil structure.
Manure and fertilizer management	NH_3, PM	• Low-till farming, alternative cereal harvesting • Covering outdoor storage of manure, including AD • Free range poultry • Ensuring sufficient manure storage capacity • Use of low protein feeding strategies • Prohibit use of ammonium carbonate fertilizers • Replacement of urea-based fertilizer with ammonium nitrate based fertilizer • Replacement of inorganic with organic fertilizers • Use of fertilizer application methods to reduce ammonia emissions • Low-emission manure spreading techniques • Adaptation of animal housing • Use of low nitrogen feed

Source: TA-9608 REG: Strengthening Knowledge and Actions for Air Quality Improvement. Review of technology and policy options for improving air quality. ADB.

Table A5: Measures to Address Industry Sector Sources of Air Pollution

Measure	Pollutant(s) targeted	Measure description
Industrial process emissions standards and post-combustion controls	PM, NO_x, SO_x, VOC	• Flue gas Dust Removal (e.g. cyclones, bag filters) • Flue gas Desulfurization • Primary NO_x control (low NO_x burners or similar) • Flue gas Denitrification (e.g. catalytic reduction) (less common than primary NO_x control) • VOC Management • Integrated treatment for Coal-Fired Boilers • Preventing leaks, and good practice on flaring • Closed storage and enclosed materials transport • Preparation and separation of raw coal (including washing) • Enclosure of coal distribution and storage centers • Establishing a clean-coal network • Energy efficiency measures • Fuel switching to cleaner fuels such as gas, Liquefied Petroleum Gas, electricity or renewables • Fuel sulfur limits • Reducing or eliminating existing, or banning construction of new, coal fired boilers • Minimum emission standards for new plant (maximum emission limit values)
Improve efficiency and introduce emission standards for brick kilns	PM, NO_x, SO_x, VOC	• Existing technologies are replaced with cleaner production techniques and technology (e.g. Hybrid Hoffman Kiln) • Regulation, supervision and enforcement program requiring upgrade/improved performance of existing facilities to meet specified standards • Closure of existing polluting facilities, if operating outside permitted levels. • Reducing production from plants if operating outside permitted production or capacity thresholds • Minimum emission standards for new plant (maximum emission limit values)
Solvent use	VOCs	• Reduction in solvent content of paints; Increased use of water-based paints, inks and coatings • Covers, seals and vapor recovery in manufacture and application of coatings, inks, adhesives, surface cleaning, and in manufacture of pharmaceutical products, vegetable oil refining, dry cleaning • Absorption, filtration or incineration of exhaust gases • Good housekeeping, solvent management plans, leak detection and repair • Cleaner production

Source: TA-9608 REG: Strengthening Knowledge and Actions for Air Quality Improvement. Review of technology and policy options for improving air quality. ADB.

Table A6: Measures to Address Energy Sector Sources of Air Pollution

Measure	Pollutant(s) targeted	Measure description
Renewables and low-carbon power generation	PM, NO_x, SO_x	• Introduction of a Feed-in Tariff (FIT) • Transition toward a low-carbon portfolio of technologies, including renewables (likely to include onshore and offshore wind, solar, hydro, and marine, as well as use of biomass), gas and nuclear power. Development of carbon capture and storage (CCS) technologies.
Upgrading existing plant	PM, NO_x, SO_x	• Introduction of advanced design units • Upgrading existing operational units • Substantial retirement of smaller, less-efficient plants • Upgrade of electrostatic precipitators (ESPs) and the inclusion of bag filters • Upgrade of the flue gas desulfurisation units (FGD) • Introduction of NO_x control systems
Demand-side energy efficiency improvements	PM, NO_x, SO_x	• Industry, commercial and large users energy audits, trainings, and certifications • Introduction of Standard Offers to large users implementing energy saving measures • Encourage residential users to use low energy appliances and devices
Active load management	PM, NO_x, SO_x	• Introduction of time-of-use pricing • Introduction of interruptible tariffs • Providing customers with smart electricity readers
Active network management	PM, NO_x, SO_x	• Support the development of network innovation projects enabling accelerated penetration of distributed renewable generation at distribution level

Source: TA-9608 REG: Strengthening Knowledge and Actions for Air Quality Improvement. Review of technology and policy options for improving air quality. ADB.

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Note:
ADB recognizes “China” as the People’s Republic of China, “Vietnam” as Viet Nam, and “Hanoi” as Ha Noi.

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